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PART ONE—SCIENCE

Elementary Text Book of Botany

BY

EDITH AITKEN



NEW YORK
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PREFACE

EVER since I began to teach Botany I have tried in vain to find an Elementary Text-Book suitable to my pupils, and to the work they had to do. At length, after several years' experience I have put together what seemed to me to be most necessary. This little Text-Book, which is the result of my efforts, is thus intended simply as an aid to teaching, to obviate the waste of time and general unsatisfactoriness of being entirely dependent on note-taking. Two or three points call for some explanation.

First, as to arrangement: while it is obvious that knowledge should grow out from the familiar to the unfamiliar, and that, therefore, well-known flowering plants should be first examined, I remember so well the vivid interest awakened in my own mind by the study of successive types in Huxley's *Biology* as originally arranged, and it still seems to me that this mode of arrangement presents such a valuable scientific idea, that I have compromised the two systems, so as to adapt the work to pupils of increasing age. Thus Part I. contains some account of the naked eye characteristics and classification of important flowering plants, and is easily

within the scope of younger girls. After such training in observation they would be ready for Part II., which consists of more detailed accounts of types increasing in complexity from the simplest upwards; and by Part II. they would be prepared to return to the study of flowering plants from the more advanced standpoint adopted in Part III. I think the three Parts together cover as much as can well be attempted in school, and on the other hand that girls who had worked carefully through the book, with due attention to Practical Work, would leave school with a fairly satisfactory elementary knowledge of the subject.

Some teachers may object to the system of selection adopted, especially in Part I., but my own experience is that a multitude of minor Orders only serves to distract attention from and muddle the memory of the important ones. I also agree thoroughly with Professor Henslow's idea that the way to grasp an Order is to study carefully, and thoroughly impress the mind with a typical example, grouping exceptional forms round the central type, to which in memory one should always return. The detailed descriptions of particular plants in the text are, of course, not intended to take the place of practical study of the plants themselves, but, coming after such study, to serve to represent the Orders, and are given as the best means by which their characteristics may be understood and remembered.

I have recapitulated at the end of each chapter the Practical Work most necessary to be done, as I have found it useful to have this put definitely before both teachers and pupils.

Of course a book of this kind pretends to no originality. I have got help from wherever I could, particularly from Bower and Vine's *Practical Botany*, and from Strasburger's *Practical Botany*. The figures of *Pythium de Baryanum* are copied from the *Quarterly Journal of Microscopical Science* by kind permission of Mr. H. Marshall Ward. My friend, Miss Ethel Sargent, of Girton College, has helped me a great deal throughout; Miss Greenwood, lecturer at Girton and Newnham Colleges, has read the proofs, and two old pupils, Miss Gertrude Stanfield and Miss Zillah Taylor, have made many drawings for me.

E. A.

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PART I.

OUTLINES OF THE EXTERNAL MORPHOLOGY AND
CLASSIFICATION OF FLOWERING PLANTS

CHAPTER I.

THE ROOT, STEM, AND LEAF.

A FLOWERING plant consists of root, stem, leaves, and hairs. A little consideration will show that every part belongs to one or other of these classes. For example, the flower consists of the end of the stem bearing leaves specially modified in connection with the formation of seed. The root and stem constantly produce lateral members like themselves, viz. branches; and the stem in addition bears lateral structures unlike itself, viz. leaves. Structures produced as outgrowths of the external layer of the plant alone are called hairs.

Concerning the Root.

The first root is produced as the descending axis of the seedling. Sometimes, as in Carrot, this grows large with-

FIG. 1A.



Primary Root.



Secondary Root.

out branching, and the root is then called primary. On the other hand, its growth is frequently arrested, so that the

root comes to consist chiefly of the branches, and is called secondary, *e.g.* Grass. Roots may also be developed from almost any part of the plant under special circumstances, as, for instance, from the stem in the case of *Geranium* cuttings,

or even from the leaves, as in *Begonia*. Such roots are called adventitious, while those formed from the radicle of the seedling are said to be true.

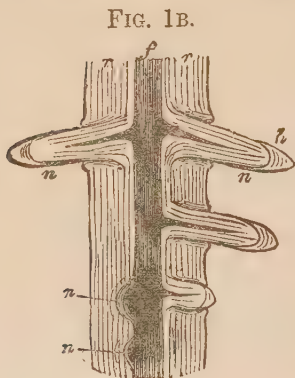


Diagram showing the way in which branch roots arise.

n, branch roots; *h*, root-cap;
f, wood; *r*, cortex.

Roots always arise from an internal layer of issue, and have to break through the surrounding parts; they are therefore called endogenous. The growing point at the tip is protected by a root-cap. The young part behind the growing point is always densely covered with root-hairs, but roots never bear leaves.

The shape of roots and of their branches varies greatly, as will be

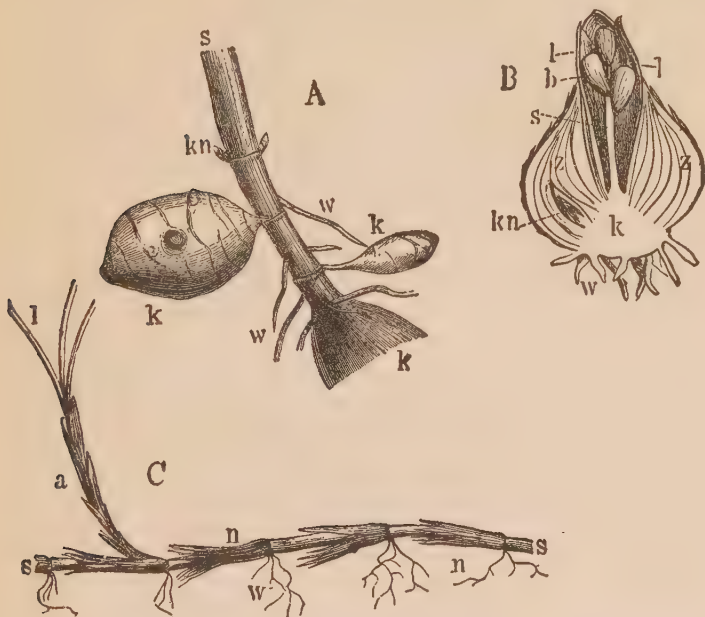
seen on comparing different examples. Roots are usually subterranean, but exceptions to this rule may be found in the aerial roots of *Orchids*, etc. There are a very few flowering plants, *e.g.* *Lemna orrhiza*, which have no roots.

Concerning the Stem.

The stem is produced as the ascending axis of the seedling. It is specially characterised by the fact that it bears leaves as well as branches. The part of the stem to which the leaves are attached is called a node, and the part between two nodes an internode. As a rule the bud of a branch arises in the axil of every leaf, though it may never develop, or only develop under special circumstances. Occasionally stems are formed adventitiously from any part of an old stem, or even from leaves. The growing point of a stem arises from the external tissues of the plant, so that stems are said to arise exogenously.

Stems are usually round and much longer than thick, but they vary greatly. Also, though they generally grow through the air, they are sometimes found in water, or may even be subterranean. For instance, in Ferns the stem creeps along

FIG. 2.



VARIOUS FORMS OF STEMS.

A.—Tubers of *Helianthus tuberosus* (one-third of natural size).—s, lower part of the stem springing from last year's tuber, k'. In the axils of the upper leaves arise the buds kn, and in those of the lower the tubers k, with very small scaly leaves and buds.

B.—Bulb of *Hyacinthus orientalis* (reduced).—k, the discoid stem; z, the scales; s, the stalk, which subsequently elongates and bears the flowers above ground, with the buds b; l, foliage leaves; w, roots; kn, an axillary bud, which becomes next year's bulb.

C.—Elongated rhizome of *Carex arenaria* (one-third).—n, scaly leaves of the rhizome s; a, erect shoot, with foliage leaves l, and scaly leaves.

underground and resembles a root. It is called a rhizome, but is known to be really a stem because it bears leaves. Again, some plants, e.g. Potato, have swollen underground stems which are called tubers, and which are only known to

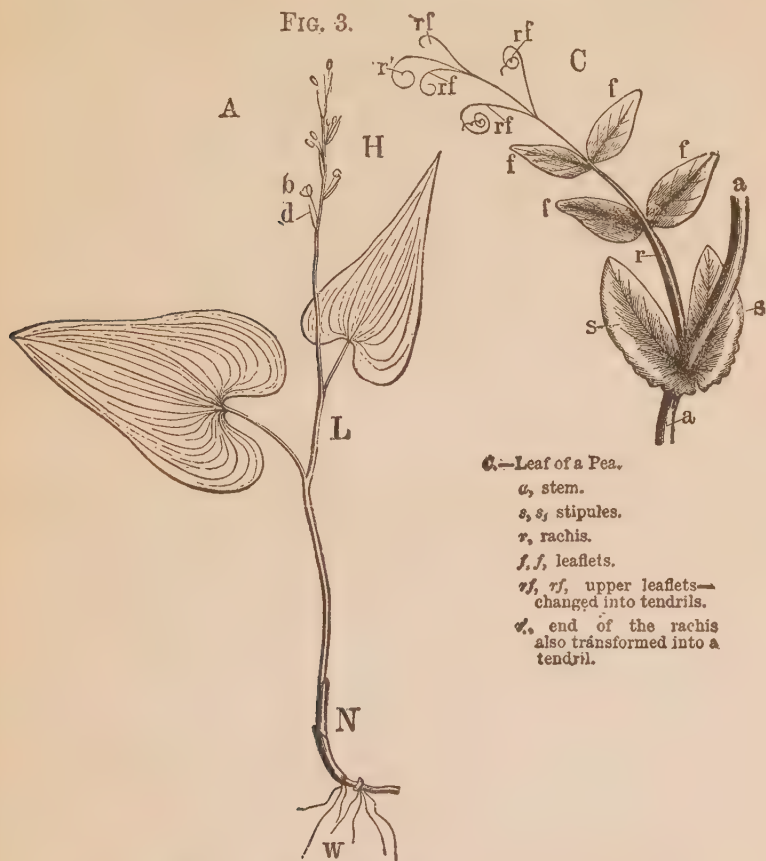
be stems because what we call the "eyes" are really buds, which, if allowed, sprout out into branches bearing leaves. In many plants, *e.g.* Columbine, the stem and leaves die down in the autumn, leaving the lower part of the stem in the ground through the winter, ready to produce fresh branches and leaves in the spring. The part which remains permanent is called the root-stock. Again, in some plants, *e.g.* many of the Lilies, buds are set free from the parent plant. They consist of a short stem surrounded by crowded, often thickened and scaly leaves. Of this nature are bulbs, bulbils, and corms. Stems may also be modified into tendrils.

The branching of stems should be noted. It is possible for the growing point itself to divide into two or more, which proceed to form branches while the original axis is lost. This may be seen in seaweeds, but is hardly found amongst flowering plants, where the usual plan is for the main axis to go on growing, while branches are formed from buds developed in the axils of leaves behind the growing point. If the main axis continues to be much more vigorous than the branches, and goes on growing indefinitely, the branching is called racemose. It is cymose when after a time the growth of the main axis is arrested, so that the branches eclipse it.

Concerning the Leaf.

The leaf is a lateral appendage of the stem unlike itself. Leaves vary greatly in form, and are capable of many transformations and adaptations. They are generally expanded horizontally on either side of a midrib, the expanded part forming the blade of the leaf. They may, or may not, be provided with a leaf-stalk or petiole. Sometimes the base of the leaf-stalk is expanded into a sheath, as in grass, or it may have lateral wings, known as stipules, *e.g.* Rose. A leaf without a leaf-stalk is called sessile. It is compound, if it consists of a number of separate leaflets; simple, if the blade is undivided. The edge of the leaf is called its margin, the part nearest the point of attachment the base, and the part furthest from this the apex.

Leaves obviously consist of lines of hard substance, called veins, with softer tissue more or less completely filling up the



C.—Leaf of a Pea.

a, stem.

s, s, stipules.

r, rachis.

f, f, leaflets.

rf, rf, upper leaflets—changed into tendrils.

r', end of the rachis also transformed into a tendril.

A.—The three forms of Leaves on the Stem of *Maianthemum bifolium* (nat. size). N, the scales; L, the foliage leaves; H, the bracts; b, the flowers in their axils; W, roots.

spaces. The arrangement of the veins, or venation, is important in distinguishing great groups of plants. Sometimes

the veins run parallel to one another all through the leaf, without much branching, as in Snowdrop. More often they form an intricate network. Net veins are called pinnate when there is one large central vein, forming a midrib, as in Rose; palmate, when several large veins radiate out from one point, as in Ivy.

The shapes of leaves vary very greatly, depending partly on the veins, and partly on the amount of soft substance covering the veins. Thus a parallel veined leaf is generally long and narrow, like Grass; a palmate leaf broad, like Geranium. With regard to the amount of soft substance, we find all stages, from a leaf whose margin is entire because the veins are completely covered, through those which have the margin indented or lobed, to those in which the divisions extend nearly or quite to the midrib.

Leaves may be transformed into tendrils. Sometimes, as in Vetch, the upper leaflets of a compound leaf are so changed while the lower ones remain unaltered. Again, they may be modified into membraneous scales, such as bud scales, and the scaly leaves on underground stems and on parasitic plants. Or the leaf may be reduced to a mere spike, while the leaf-stalk becomes expanded and leaf-like, forming what is called a phyllode, as in Australian Acacias, where the phyllode, being expanded vertically, gives much less shade than an ordinary leaf. The most important modifications of leaves are in the flower, where not only are leaves specially modified to assist in the formation of seeds, but the neighbouring leaves are also more or less altered, as bracts, sepals, and petals, for purposes of protection, etc.

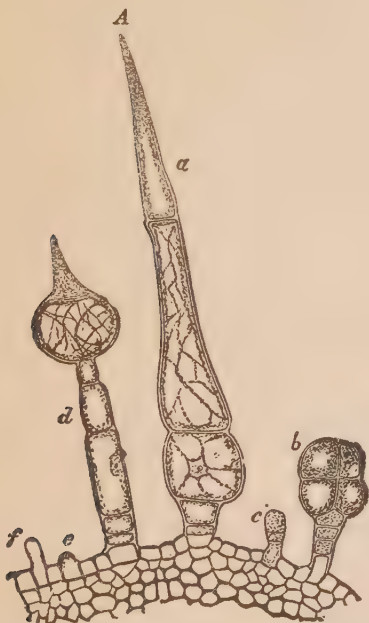
Concerning Hairs.

Hairs are formed from the external layer of the plant only and are usually thin and delicate. The most important are the unicellular root hairs which clothe the young parts of a root, and attach it to the soil. Stems and leaves also often have their surface greatly extended by being covered with hairs. Some hairs, however, are more compli-

cated, being stellate and glandular, and hair-like structures are found projecting into the intercellular spaces of water-plants.

Prickles are purely external structures, and though they are not outgrowths solely of the external layer, they must be considered as hardened hairs. They are sometimes called emergences to distinguish them from ordinary hairs. Thorns, on the other hand, are modified branches.

FIG. 4.

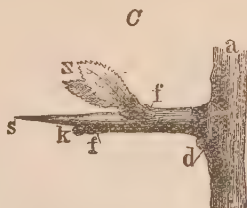


A.—Transverse Section of Epidermis and subadjacent tissue of ovary of *Cucurbita* ($\times 100$).

a, hair of a row of cells; *b*, *d*, glandular hairs in different stages of development; *c*, *f*, *e*, youngest stages of development of glandular hairs. (After Prantl.)



B.—Prickles on the stem of Bramble (nat. size).



C.—Thorn of the Sloe.

a, branch.

d, leaf-scar, from the axil of which the thorny branch, *s*, springs; on the thorn are *f*, *f*, leaf-scars; in the axil of the upper one is the branch, *z*, in that of the lower the bud, *k*.

Later on, we shall find other examples of modified hairs amongst the reproductive organs of Mosses and the sporangia of Ferns, which are outgrowths of the external layer of these plants.

CHAPTER II.

THE STRUCTURE OF THE FLOWER.

THE flower consists of a stem, bearing leaves. It is therefore a branch, but differs from an ordinary branch in two respects :—firstly, the leaves are modified in connection with the process of forming seeds ; and secondly, they are crowded together by the shortening of the internodes of the branch.

The parts of the flower are sometimes arranged spirally, as in an ordinary branch, *e.g.* Water-lily, where also the transition from the form shown by the outer leaves of the flower to that of the inner is gradual. Usually, however, the leaves of the flower are arranged in four distinct whorls or circles, distinguished from the outside inwards as :—

Calyx,	composed of sepals.	
Corolla,	„	„ petals.
Androecium,	„	„ stamens.
Pistil,	„	„ carpels.

The flower-stalk is called the peduncle, and the leaves which it bears, bracts. When the leaves composing a whorl are alike, that whorl is said to be regular ; if otherwise, ~~ir~~regular. As a rule the parts of neighbouring whorls alternate ; thus a petal is placed between two sepals, and a stamen between two petals. It is quite an exception to have a petal opposite a sepal, or a stamen opposite a petal.

The calyx, or most external whorl of the flower, is generally, though not always, green. The sepals may be united or free. The petals are generally bright coloured, with various markings, and they frequently bear honey glands, or nectaries. The sepals and petals serve to protect the stamens and carpels, and to attract insects to the flower by their colour, scent, honey, etc. It is the stamens and carpels which

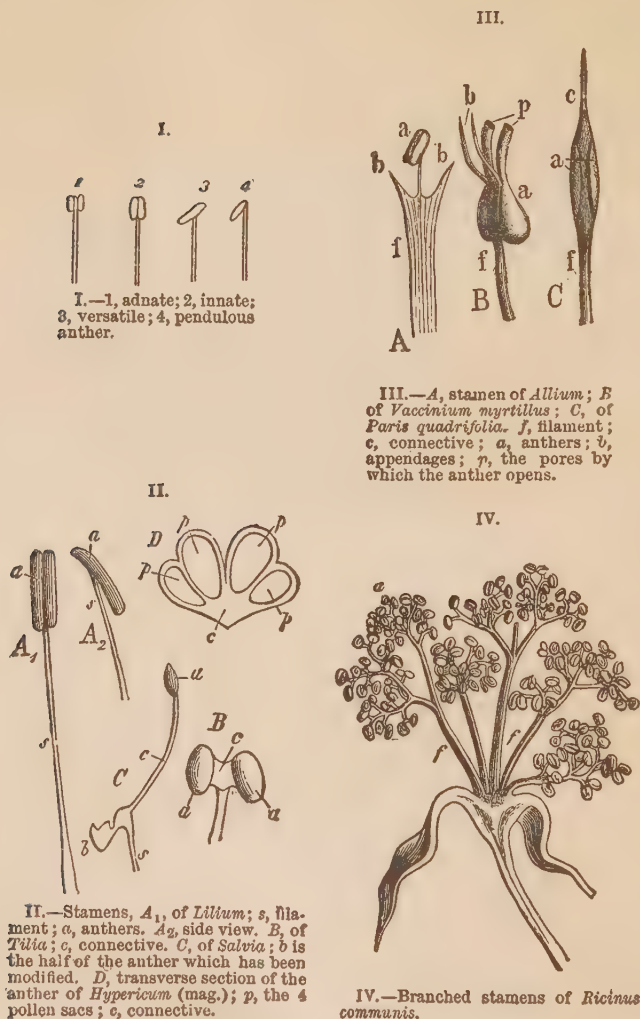
form the essential part of the flower, for they are concerned in the production of seed. The calyx and corolla are sometimes alike, and together form the perianth.

A stamen has two parts, the filament corresponding to the stalk of a foliage leaf, and the anthers, which represent the folded-up halves of the blade. The part joining the two anther lobes is called the connective. Each anther lobe usually contains two tiny sacs of the dust which we call pollen. Sometimes, as in Violet, the filament is very short, when the anther is called sessile. When there is no joint between connective and filament, the anther is said to be adnate, as in Snowdrop; if there is a joint at the base of the connective, as in Wallflower, it is innate; if the joint comes in the middle, versatile, *e.g.* Tiger-lily; or if at the top, pendulous (*see* FIG. 5). These different modes of attachment of the anther are important, as the scattering of the pollen depends on them. For instance, it is evident that if it is necessary to the flower to scatter its pollen into the air, versatile anthers will be the most useful. Sometimes the connective is curiously developed, as in sage, separating the anther lobes, so that the stamen becomes T-shaped.

To let the pollen escape the anthers split, and this split may be longitudinal—that is, along the anther—or transversely, across it, or sometimes the pollen escapes by small holes or pores, as in the heaths. When the splitting or dehiscence takes place on the face of the anther towards the pistil, it is said to be introrse; if at the back, extrorse; if at the sides, lateral. Notice, however, that the split is always towards a nectary, and therefore towards any insect entering the flower.

Sometimes the stamens are united by their filaments into a group (monadelphous); or into two or more groups (di- or poly-adelphous). In a few cases, as in flowers of the Order Compositæ, the stamens are united by their anthers, when they are called syngenesious. In the Mallow family the filaments branch, each branch bearing an anther. In Primrose the filaments are adherent to the corolla, and in Orchids they are united with the pistil. Sometimes no

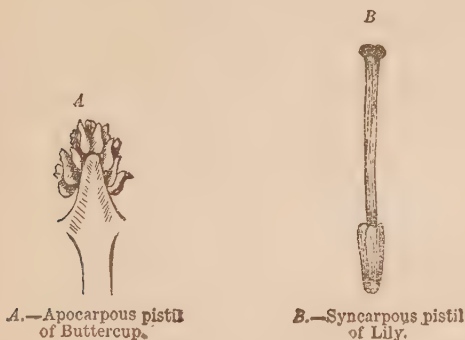
FIG. 5.



anther is formed, and the stamen is then no true stamen, but is called a staminode. In some of the Orchids the pollen grains adhere together, and form masses called pollinia.

The pistil completes the growth of the stem, which never afterwards lengthens. It consists of one or more leaves or carpels, and is called, if the carpels are free from one another, as in Buttercup, apocarpous; if they are united, as

FIG. 6.



in Lily, syncarpous. Each carpel has three parts, the stigma, the style, and the ovary.

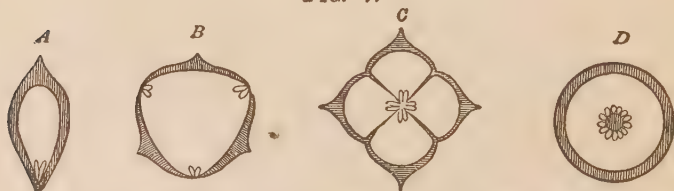
The stigma is the upper end of the carpel. Sometimes it is evidently distinct from the style, but very often it only appears as the upper end or side of a carpel. It is distinguished by rows of little swellings, called papillæ, or sometimes by hairs, and by the formation when mature of a sticky substance.

The style is the middle part of the carpel. It is oftenest long and round, and proceeds from the top of the ovary, but it varies in length and shape, and sometimes arises from the side, or even from the base of the ovary. In most cases it is solid, the interior consisting of loose connecting tissue. It may, however, be hollow, as in Violet.

The ovary is a little chamber formed by the folding together of the carpellary leaf, which contains the ovules,

borne on the carpels. The part of a carpel to which the ovules are attached is called the placenta, and is generally found along the edge of the carpellary leaf (marginal), though sometimes all over the inner surface (diffuse). The placentation, or arrangement of the ovules, varies according to the way in which the carpels are folded. Thus if we have a single carpel with its two edges folded together, the placentation is sutural, as in Pea. If two or more carpels are joined by their edges, so that the placentas come on the walls of the ovary, the placentation is parietal, *e.g.* Violet. But if the joined edges are bent in so as to meet in the middle, it is axile, as in Hyacinth. Again ovules are sometimes found erect on the floor of the ovary, as in Sunflower, or pendulous from its roof, as in Teazel. A special kind of basal placenta is found in that usually known as free central. Here we find the ovules borne in the centre of the ovary on a kind of pedicel, which is an outgrowth from the bases of the carpels. This pedicel is the only connection between the ovules and the walls of the ovary.

FIG. 7.



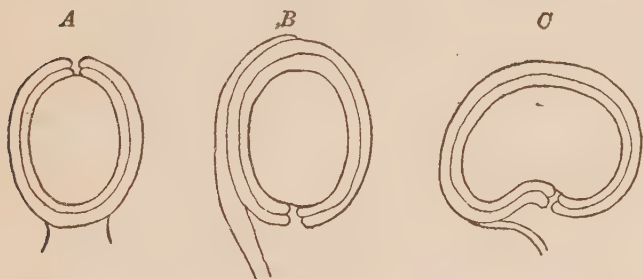
PLACENTAS.—A, sutural; B, parietal; C, axile; D, free central.

The ovule, in ordinary flowering plants, consists of a central mass of cells, the nucellus, surrounded by two coats, the primine and secundine, which, however, leave an opening to the interior, the micropyle. The stalk, or funicle, enters the ovule at the chalaza. Sometimes it is adherent along the side of the ovule, and the attached part is then called the raphe.

Ovules are of three kinds. In Fig. 8, A, the nucellus, is

straight, with a short stalk, and the micropyle exactly opposite. We find this, the orthotropous ovule, in Yew. In *B*, the nucellus is also straight, but inverted. The funicle is long. It joins the ovule at one side, and then runs along to the end as a raphe before really entering the ovule at the chalaza, which is here also opposite the micropyle, *e.g.* Lily. In *C*, the nucellus is curved, and there is only a short raphe, so that the micropyle and chalaza are near together, *e.g.* Bean. Traces of the above can be found in any mature seed, the funicle leaving a scar when it is separated.

FIG. 8.



OVULES.—A, Orthotropous; B, Anatropous; C, Campylotropous.

The pistil is always the last formed part of the flower, but its position varies according to the form assumed by the summit of the stem, which is known as the receptacle or thalamus. When the receptacle is conical, as in Buttercup, the pistil is superior, the calyx inferior, and the stamens and petals hypogynous (*hypo*=below, *gyne*=pistil). On the other hand, the parts behind the end of the stem may increase in size so much as to form a more or less cup-shaped receptacle, as in Rose. The carpels are then in the hollow of the cup, and are still superior to the stem. The calyx is called inferior, and the petals and stamens perigynous, all these being placed round the edge of the cup (*peri*=around). When, however, the carpels become indistinguishably combined with the cup, which happens, for instance, in Snowdrop,

the pistil is called inferior, the calyx superior, and the petals and stamens epigynous (*epi*=above).

FIG. 9.

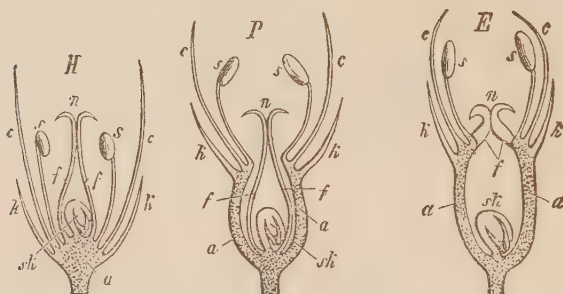


Diagram of, *H*, hypogynous; *P*, perigynous; *E*, epigynous flowers. *a*, axis; *k*, calyx; *c*, corolla; *s*, stamens; *f*, carpels; *n*, stigma; *sk*, ovule.

Concerning the Arrangement of Flowers, or their Inflorescence.

Since flowers are modified branches, their arrangement follows the ordinary laws of branching. Thus the two chief kinds of inflorescence are:—

1. The Racemose, where the main axis goes on growing.
2. The Cymose, where the growth of the main axis is stopped by the formation of a flower.

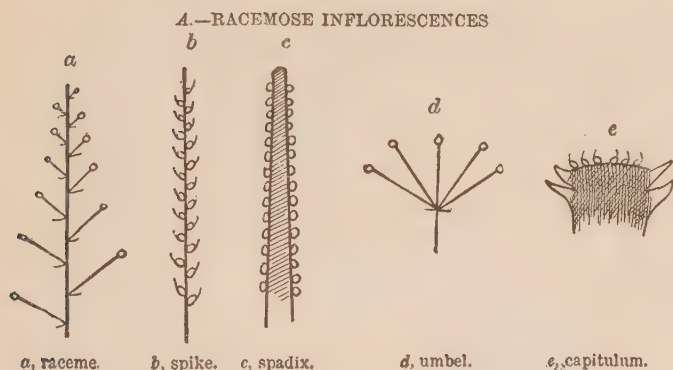
1. Some racemose inflorescences have an extended axis. Such are the raceme, where each flower has its own little stalk or pedicel, *e.g.* Wallflower; the spike, where the flowers are sessile, *e.g.* Orchid; and the spadix, where a fleshy axis bears sessile flowers, *e.g.* Arum.

When, on the other hand, the axis is short, we get the umbel, with pedunculate flowers, *e.g.* Wild Carrot, and the capitulum, with sessile flowers, *e.g.* Daisy.

2. A cymose inflorescence, consisting of only one flower, is called a scape, *e.g.* Snowdrop.

The cyme proper is produced when several flowers of equal importance are given off below the terminal flower, *e.g.* Spurge. A special case, the dichasial cyme, occurs very commonly, with only two such branches. If only one branch is given off below the terminal flower, the cyme becomes scorpioid if

FIG. 10.



B.—CYMOSE INFLORESCENCES.



the branches are alternately on the two sides of the axis, as in Borage ; or helicoid if the branches are always on the same side, as in Forget-me-not. The helicoid cyme has been by some regarded as a one-sided raceme.

Inflorescences are often compound, the branches of the main axis being themselves branched. The secondary branch is sometimes like and sometimes unlike the primary.

CHAPTER III.

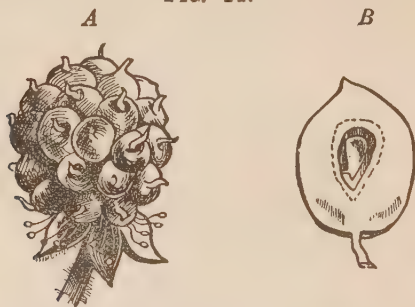
THE FRUIT.

THE ovules become transformed into seeds, and the wall of the ovary ripens into a case for the seed, called the pericarp. The pericarp and seed together compose the fruit

A fruit thus formed from the ovary and its contents alone is called a true fruit; if any other part of the plant shares in the formation of the fruit, this is called spurious.

Amongst true fruits we find some in which the pericarp is juicy or succulent, and others in which it is dry. A juicy pericarp generally exhibits three layers—the skin or epicarp,

FIG. 11.



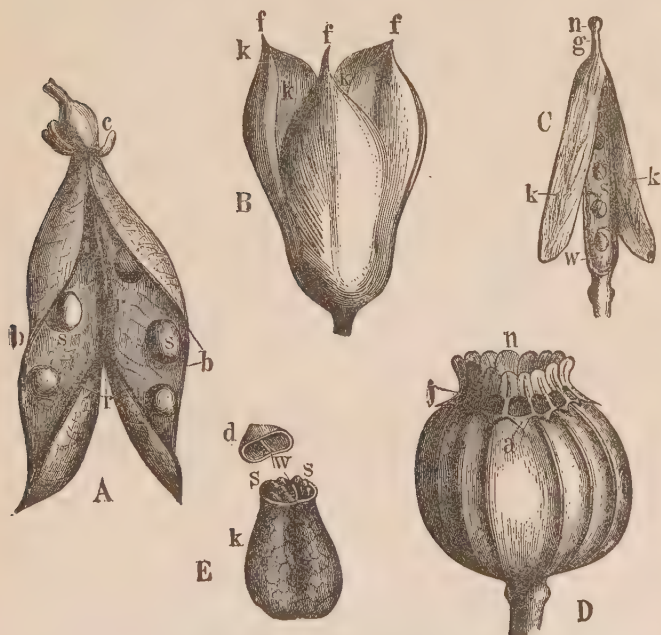
A.—Compound drupe of Blackberry.

B.—Section of a single drupelet.

the flesh or mesocarp, and the endocarp immediately surrounding the seed. Fruits like the Grape have a soft endocarp, and are called berries, which are simple if, like the Grape, they have only one division, or compound if, like the Orange, they have several. On the other hand, in many fruits the endocarp is hard and woody, forming the stone. Such fruits are called drupes, *e.g.* Plum. We have also compound drupes, *e.g.* Blackberry and Raspberry.

Amongst dry fruits we must distinguish between the dehiscent ones, which split open to allow the seeds to escape, and the indehiscent ones, which do not open. A dehiscent dry fruit may be formed from one, two, or more carpels. If from

FIG. 12.



DRY DEHISCENT FRUITS.

A.—The pod (legume) of the Pea ; *r*, the dorsal suture ; *b*, the ventral ; *c*, calyx ; *s*, seeds.

B.—The capsule of Autumn Crocus ; *f*, *f*, *f*, the three separating carpels.

C.—Silique of Brassica ; *k*, the valves ; *w*, the replum ; *s*, seeds ; *g*, style ; *n*, stigma.

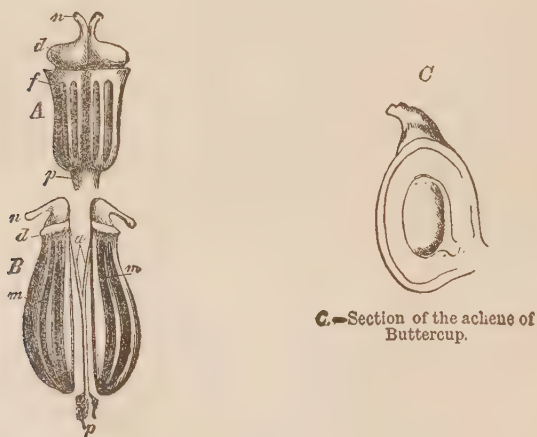
D.—Capsule opening by pores of Poppy ; *n*, stigma ; *j*, the pores which open only by the removal of the valves *a*.

E.—Capsule of Hyoscyamus ; *d*, the lid ; *w*, partition ; *s*, seeds.

one carpel, it may be a follicle, splitting down only one side, like the fruit of Hellebore ; or a pod (legume) splitting down both sides, as in Pea ; or a lomentum, with transverse partitions, as in Sainfoin. If formed from two carpels, we get a fruit

like that of Wallflower, called a siliqua. The edges of the two carpels are joined by a spurious partition, the replum. When ripe, the carpels split away from below upwards, leaving the seeds attached to the replum. If, as in Shepherd's Purse, the fruit is of this structure but broader, it is called a silicula. The replum may be narrow, as in Shepherd's Purse, or very broad, as in Honesty. When the fruit is formed from several carpels it is called a capsule,

FIG. 13.



TWO-SEEDED DRY INDEHISCENT FRUIT OF *CARUM CARUI*.

A.—Pistil of the flower; *f*, ovary; *d*, bases of the styles forming disc; *n*, stigmas; *p*, peduncle.

B.—Fruit of the same which has divided into two mericarps, separating from the carpophore or prolongation of the peduncle.

as in Poppy. In Poppy the capsule dehisces by pores, but it is more usual for it to open either by the carpels separating from one another, or by longitudinal splits along each carpel.

Indehiscent dry fruits may be one-seeded or many-seeded. We get examples of one-seeded dry indehiscent fruits in the Nut, where the pericarp is hard, and in Buttercup, where the pericarp is membranous, the latter fruit being an achene.

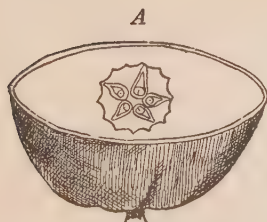
The inferior achene of the Compositae is sometimes called a cypsela, and that of the grasses, to which the perianth closely adheres, is a caryopsis. In an indehiscent dry fruit containing several seeds, the carpels, without opening, generally split apart, so as to distribute the seeds. For example, in the *Geranium*, the five carpels surrounding the prolonged axis, when ripe, curl up, and drop off separately, carrying the seeds with them. Fruits of this kind are called schizocarps (Fig. 13).

Spurious fruits vary greatly, different parts of the flower taking part in the formation of the fruit in different cases. To consider a few of the commonest examples :—

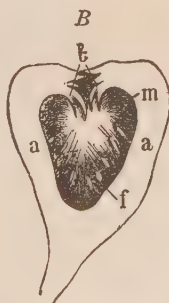
The fleshy part of the Strawberry is derived from the receptacle or end of the stem. The true fruits are the yellow so-called “seeds” found on the outside.

In the Apple the cupshaped receptacle develops and forms a fleshy case to the true fruits which form the core. Fruits like Apple are called pomes.

FIG. 14.



A.—Pome showing the five true fruits of the core surrounded by the fleshy axis.



B.—Longitudinal section of a Fig (nat. size); *a*, the fleshy axis of the inflorescence; *f*, female; *m*, male flowers; *b*, bracts.

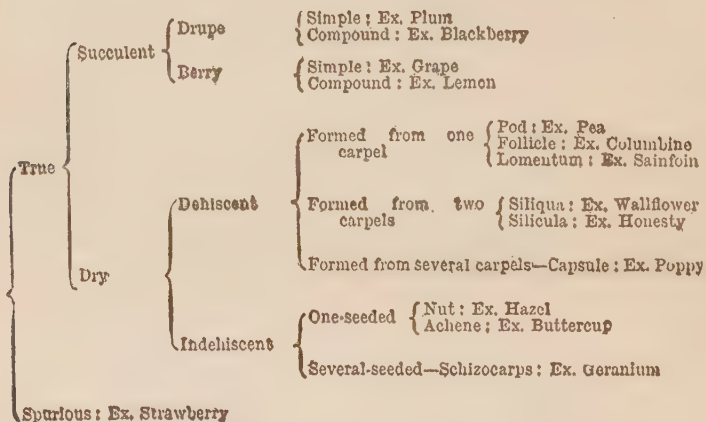
In the Fig, the stem, bearing a number of flowers, is cupshaped. It becomes succulent and closes over the remains of the flowers, forming a syconus. The true fruits are the hard grains inside.

On the other hand, in Pineapple and Mulberry the complete

flowers of a whole inflorescence, and in Pineapple the axis also, become fleshy, giving rise to a sorosis.

Sometimes a husk or cupule of scaly leaves is formed after fertilisation below the fruit. We find this in the cup of Acorn and in the case surrounding Beech nuts.

The above account may be summarised in the following classification of fruits.



CHAPTER IV.

A DESCRIPTION OF *PINUS SYLVESTRIS*, AND ITS CLASSIFICATION AS A GYMNOSPERM.

THE Vegetable Kingdom has been classified in several different ways, the two chief being the Linnaean and the Natural. The Linnaean, introduced by Linnaeus, the great Swedish botanist, classifies plants by reference to the number of stamens and carpels only. This is often a very convenient means of easily identifying a plant, but, since it separates plants whose whole structure shows them to be nearly related, it cannot be considered satisfactory. The Natural system takes account of the whole plant, though giving chief importance to the essential organs of the flower, and is therefore much more truly scientific than the Linnaean.

According to the Natural system, the vegetable kingdom is divided into four great groups of plants:—

- I. The **THALLOPHYTES** (*thallus*=a mass, *phuton*=a plant), including all plants not distinguished into stem and leaves, *e.g.* sea-weed.
- II. The **MUSCINEAE**, including plants which have stem and leaves, but no true roots, etc., *e.g.* mosses and liverworts.
- III. The **PTERIDOPHYTA** (*pteris*=a fern), including plants which have root, stem, and leaves, but which do not form seed, of which the ferns are the chief examples.
- IV. The **PHANEROGAMIA** (*phaneros*=evident, *gamos*=union), commonly known as flowering plants, but distinguished especially by the fact that they form seeds.

Postponing for the present any consideration of the three first groups, we must first remark that since plants belonging to other groups have organs as conspicuous as, and now known to be of the same nature as, flowers, the names *Phanerogamia* and "flowering plants" are misleading. Their use is, however, so well established that they cannot, at any rate here, be changed. It must always be borne in mind however, that the real difference which distinguishes this group from the others is that here for the first time we find the formation of seed.

The **PHANEROGAMIA** have two divisions:—

1. **THE GYMNOSPERMS** (*gymnos*=naked, *sperma*=seed), where the ovules are exposed to the air, generally in cones.
2. **THE ANGIOSPERMS** (*angion*=a vessel), where the ovules are enclosed in an ovary.

The Scotch fir, may be taken as a typical example of a Gymnosperm.

Order Coniferae.

The Scotch Fir. *Pinus sylvestris*.

The Scotch Fir, the only pine now native to Britain, is a tall evergreen tree, conical in shape when its development is not interfered with: The primary stem is very strongly developed, and the branches are given off almost horizontally, often appearing to be whorled, though not really so. The leaves are of two kinds: small brown scaly leaves on the main branches, and, in the axils of these, dwarf shoots with shortened internodes, each bearing two long dark green needle-shaped leaves. The stamens and carpels appear in separate cones.

The stamens are arranged in short catkins. Each consists of a minute scale bearing two anther lobes on its inner surface, and these are closely imbricate.

The carpels are found as scales at the base of bracts, which

also are arranged in an imbricate manner to form catkins or cones. Each carpellary scale bears two ovules. The effect of

FIG. 15.



ABIES PECTINATA.

- I.—A, a bract with the carpellary scale *s*, bearing the ovules *sk* (mag.).
 B, upper part of the carpellary cone when mature; *sp*, floral axis; *c*, bracts; *s*, the much developed carpellary scales.
 C, a ripe carpellary scale with the two seeds *sa*; *f*, the wing of the seed (reduced).
 II.—A, staminate cone; *b*, bracts; *a*, stamens.
 B, pollen grain (highly mag.); *e*, extine expanded by air; *i*, intine; *y*, the included cells.

the pollen grains on the ovules is known as fertilisation. The details of this process and of the structure of the pollen

grains and ovules will be considered further later on. At present it is enough to say that the pollen grains are carried to the ovules by the wind in dense clouds, forming what is popularly known as "flowers of sulphur." Fertilisation, however, by which the ovules are enabled to grow into seeds, does not, in this particular example, take place till the following year, when, within the fertilised ovule, that is, within the seed, an embryo plant is gradually developed, consisting of a little root, called the radicle, a first stem shoot, the plumule, and seed leaves or cotyledons. At the same time the seed develops externally a long wing, which helps in the subsequent distribution by the wind.

Spruces, Cedars, Cypress, Araucaria, Larch, the Wellingtonia or Giant Pine of California, Juniper, Yew, etc., all belong to the Order Coniferae, and differ only in details from the type described above. In these plants there are generally several leaves on each dwarf shoot, and in the Larch the leaves are deciduous. In the Yew the ovules are borne singly, and naked on the axis, with bracts. The mature ovule becomes invested by a pink fleshy cup, called an arillus, an extra coat to the seed.

Many of the Coniferae yield valuable wood, used for masts of ships, etc. The wood of Scotch Fir is popularly known as "Yellow Deal," that of Norway Spruce as "White Deal." The wood of Larch is used for railway sleepers; that of Yew trees, which often attain a very great age, is said never to be attacked by insects. The trees of this Order also yield resin, tar, and turpentine.

The Cycads are allied plants. They differ from the Conifers in their swollen unbranched stems and large, thickly-set, much-divided leaves. There are also some Gymnosperms where the stamens are surrounded by an imperfect perianth.

CHAPTER V.

A DESCRIPTION OF TYPICAL EXAMPLES OF THE MONOCOTYLEDONS & THEIR CLASSIFICATION.

COMING now to the **ANGIOSPERMS**, we find this division to consist of two very distinct classes, the **MONOCOTYLEDONS** and the **DICOTYLEDONS**, characterised as follows :—

MONOCOTYLEDONS have	DICOTYLEDONS have
(1) one seed leaf in the embryo	two seed leaves in the embryo ;
(2) a secondary root ;	generally a primary root ;
(3) a stem which does not increase in thickness, and which has its wood in scattered bundles ;	a stem which increases in thickness, and which has its wood arranged in a ring ;
(4) long narrow leaves with parallel veins ;	broader leaves with net veins ;
(5) three or six parts in each whorl of the flower.	four, five, or eight parts in each whorl of the flower.

Amongst the **MONOCOTYLEDONS** we distinguish two sub-classes :—

The **Petaloidae**, with a conspicuous perianth.

The **Nudiflorae**, with an imperfect, often scaly perianth.

The above classification will be rendered clear by the following examples :—

Sub-class **Petaloidae**.

Order **Liliaceae**.

Wild Hyacinth. *Scilla nutans*.

The Wild Hyacinth is a bulbous plant. In its early stages it consists of a small underground stem surrounded by thick

sealy leaves, forming a bulb. About May or June the stem

FIG. 16.



Wild Hyacinth.

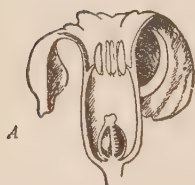
lengthens, and it produces long green foliage leaves, and a raceme of blue bell-shaped flowers. The perianth has six parts, united at the base, and inserted on its tube are found six stamens. The pistil, composed of three united carpels, is superior. At the base of the pedicel of each flower are two delicate pointed bracts.

The fruit is a capsule.

After flowering the axis dies away. Buds are formed in the axils of the bulb scale, which grow into next year's bulbs.

Floral formula, $K_3, C_3, A_3, + 3, G^{(3)}$.

FIG. 17.



A.—Vertical section of flower of Wild Hyacinth.



B.—Horizontal diagram of same.

The Liliaceae are usually herbs, but *Yucca* and *Dracaena* and some species of *Aloe* are tree-like, and the stem of *Dracaena* is even capable of a certain amount of growth in thickness. In many flowers of the order, as in *Tulip*, the perianth segments are free and the stamens hypogynous. In *Asparagus*, etc., the fruit is a berry. *Herb Paris* is an exception to the rest, in that its whorls consist each of four instead of three

parts, and the stem also bears an involucre of four leaves below the flower. In Butchers' Broom the flowers are borne on leaf-like branches which arise in the axils of minute scaly leaves. Colchicum, the autumn Crocus, is peculiar in its mode of flowering. In the autumn an underground stem bears flowers which have a long stalk-like perianth and the ovary underground. In the following spring the stem swells into a corm and lengthens, carrying leaves and ovary above ground, so that the seeds may be distributed. A lateral shoot is given off underground which, next autumn, forms a flower.

The following characteristics of this order can be deduced from an examination of numerous examples :—

The plants are usually herbs.

The perianth segments are petaloid.

There are six stamens.

The pistil is superior.

Examples are : various kinds of Lily, New Zealand Flax, Fritillary, Squill, Onion, with hollow leaves, Lily of the Valley Smilax, Solomon's Seal, Aloe, Crown Imperial, with a crown of leaves surmounting the flower, etc.

Order Amaryllidaceæ.

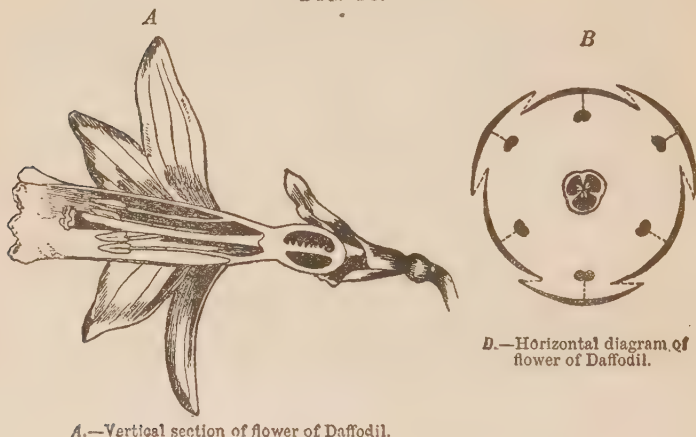
Daffodil. Lent Lily. *Narcissus Pseudo-Narcissus.*

Dáffodil is a bulbous plant, found wild in many parts of England. It has rather a large bulb, and long, narrow, parallel-veined, blueish-green leaves. The inflorescence is a scape; that is, there is a stem rather longer than the leaves, bearing a single large, scentless, yellow flower. Just below the flower is a large scarious bract. The perianth is tubular, about an inch long, divided at the top into six ovate, spreading segments, as long as the tube. Within these is the crown or corona, yellow, tubular, and often longer than the perianth; this must be considered as formed by the union of ligules belonging to the perianth segments. It is often six-lobed, with a wavy outline, slightly curved outwards at its edge. The size and colour vary in different specimens. There are six introrse stamens, attached to the base of the perianth tube.

The ovary is inferior, composed of three united carpels, three-celled, with axile placenta. The fruit is a capsule, opening by three valves. The seeds contain endosperm.

Floral formula, $K_3, C_{3+3}, A_{3+3}, \bar{G}_{(3)}$.

FIG. 18.



A.—Vertical section of flower of Daffodil.

B.—Horizontal diagram of flower of Daffodil.

Many of the most lovely plants of gardens and hothouses belong to this Order. For instance, Snowdrop and Snowflake, which have no corona, but their perianth divided into segments to the base. In *Amaryllis* the flowers are unequally toothed. In *Narcissus* the corona is yellow or brown, while the perianth is white. The so-called Aloe (*Agave americana*) belongs to this order. It is popularly supposed to flower only once in a century, because the plant, which bears a thick rosette of prickly leaves, does not attain sufficient vigour to throw up its floral axis and pyramid of flowers for a considerable period, from ten to twenty years.

Characteristics of the Order Amaryllidaceae.

Most plants of the order have a short, often bulbous stem.

The ovary is inferior, a point of distinction from the lilies.

The perianth has usually a corona, and is sometimes irregular.

Order Iridaceae.

Yellow Flag. *Iris pseudacorus*.

The Yellow Flag grows in wet meadows and marshes. It has a thick horizontal root-stock with numerous fibres. The stem is about two feet long, and bears long, narrow, stiff, erect leaves, of grayish colour, from one to two inches broad, the lower ones much longer than the upper, and placed across the stem. The flowers are large and showy—yellow, with brown markings, two or three together in the axil of a sheathing, scarious bract. The three outer perianth segments are broad and spreading above, contracted into a claw below; the inner are erect and much shorter, the lower part covered by coloured hairs. The pistil consists of three united carpels, the three stigmas being large and petaloid and overhanging the stamens, of which there are only three, placed opposite the divisions of the pistil. The fruit is a capsule, opening by three valves, and enclosing light brown seeds.

FIG. 19.



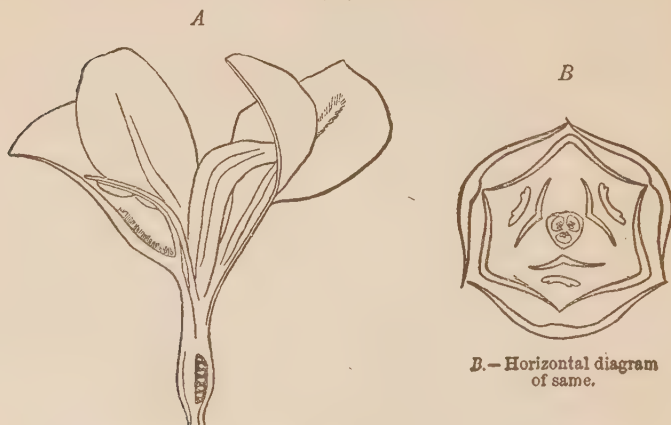
Iris pseudacorus.

Floral-formula, $K_3, C_3, A_3 + O, \overline{G}_{18}$.

Gladdon, the foetid Iris, has a fruit consisting of a pale green capsule with bright red seeds. Gladiolus has a many-flowered inflorescence of oblique flowers. Crocus, like Colchicum, has a long narrow perianth tube going down into the ground, and a subterranean ovary. Saffron is made from its stigmas, which are expanded, and much cut and fringed. There are two varieties, Spring Crocus and Naked

Crocus, only found wild in Britain in the meadows round Nottingham, and a few other places in the Midlands.

FIG. 20.



A.—Transverse section of flower of Iris.

B.—Horizontal diagram of same.

Characteristics of the Order Iridaceae.

This order, which strongly resembles Liliaceae and Amaryllidaceae, is distinguished from the former by the inferior ovary, and from both by its stamens and peculiar stigma.

The leaves are equitant; that is, they are expanded in the median plane.

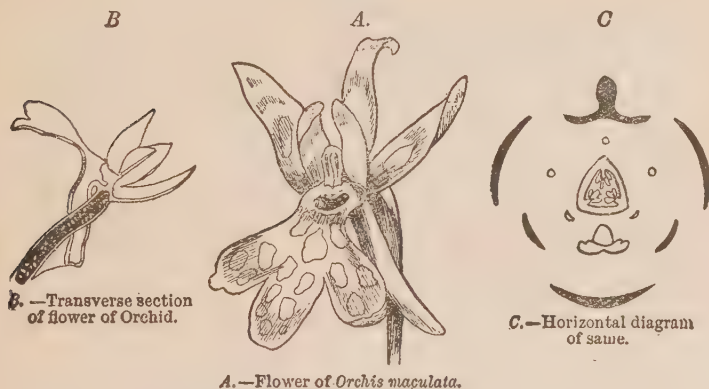
Order Orchidaceae.

The Spotted Orchid. Orchis maculata.

This Orchid is common all over Britain, in meadows, pastures, and open woods. It flowers in summer. Underground are two tubers. In each year one tuber, formed the year before, grows out into the flowering axis, usually about a foot high. At the upper end of this first tuber a second one is formed, having at its apex next year's bud. These tubers are really formed by the coalescence of a branch stem and its first root. They are rather flat, and divided into two or three palmate

lobes, the ends of which have the structure of roots. The leaves are parallel veined, but rather broad, varying from lanceolate to ovate, and marked with dark spots. The flowers form a dense oblong spike. They are irregular, and vary a good deal in colour, and in the spots and markings of a darker tint. At the base of each is a leafy bract with several veins, the lower bracts longer, the upper shorter, than the flowers. The perianth consists of six petaloid segments. The three outer and the two front inner segments are much alike, but the back inner segment, which by the twisting of

FIG. 21.



A.—Flower of *Orchis maculata*.

the ovary becomes the front, is much larger, and is three-lobed and spurred. It is called the lip or labellum, and is the most conspicuous part of the flower. Of the six stamens one would expect to find we actually get in the outer whorl a single front stamen (back after twisting), and in the inner, staminodes representing the two front inner stamens (see diagram), the rest being entirely wanting. The filaments of the stamen and of the two staminodes are united with the three styles to form what is called the gynostemium or column. We find two pollen sacs, one on each side of this column, each filled by a mass of coherent pollen grains, known as a pollinium. Part of the stigma is modified into a sticky mass

called the rostellum. Fertilisation is carried out by means of insects, as will be described later. The inferior twisted ovary is one-celled, with three parietal placentas to which are attached numerous anatropous ovules, which are very small. The fruit is a capsule opening by three valves.

Floral formula, $K3, C3, A1 + \overbrace{2}, G_{(3)}$.

In many Orchids the tubers are simple and rounded. Many tropical orchids grow from trees, and obtain moisture by means of their curiously modified aerial roots. The arrangements to secure cross fertilisation bring about the most extraordinary forms of flowers in such Orchids as the Mexican Grasshopper and the Cradle Orchid, etc. Vanilla is derived from the fruit of a tropical Orchid. Some British specimens, e.g. *Neottia*, the Bird's Nest Orchid, are destitute of chlorophyll and are parasitic on the damp soil of woods, etc. As other common examples of English Orchids may be mentioned the Early, the Military, the Greenwinged, the Pyramidal and the Sweet-scented Orchis, the Bee, the Spider, and the Fly Ophrys, Twayblade, Lady's Tresses, the Butterfly Habenaria, and many others.

In one genus we find two fertile stamens and one conspicuous staminode, e.g. Lady's Slipper.

Characteristics of the Order Orchidaceae.

The Order is sufficiently characterised by the very peculiar structure of the flower, and especially by the gynostemium as described above.

Order Juncaceae.

The rushes have flowers of precisely the same structure as those of the Liliaceae. The floral formula is exactly the same.

Floral formula, $K3, C3, A3 + 3, G_{(3)}$.

They differ, however, considerably in appearance and habit. The perianth leaves are dry and glumaceous, brownish green in colour, except in *Asphodel*, where they are bright yellow and the foliage leaves sword-shaped. The leaves of Rush are generally long and tubular. Their pith may be extracted, and

consists of beautiful star-shaped cells. The inflorescence is compound, and is displaced by a bract which looks like part of the stem, and makes the inflorescence seem lateral. Rushes are bog plants, and grow in great masses.

This order forms a transitional link between the petaloid Liliaceæ and the Gramineæ or grasses, which have imperfect scaly flowers, and which therefore must be placed in the Sub-class Nudifloræ.

Sub-class **Nudifloræ.**

Order Gramineæ.

Meadow Grass. *Poa annua*.

This plant has a secondary, fibrous root. The stem, called in this order the haulm, is round, and hollow except at the nodes. It is surrounded by the sheath of the leaf, which is split down one side. At the base of the blade of the leaf,

FIG. 22.



A.—Section of flower of Meadow Grass.

B.—Horizontal diagram of the same.

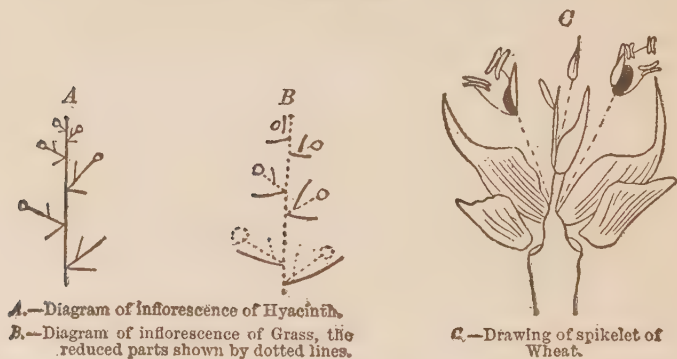
where this joins the sheath, is an appendage, called a ligule. The leaf is long and narrow, with parallel venation. The flowers are very small, arranged in a compound inflorescence, and are on the same plan as those in the Liliaceæ, but much reduced.

In each flower the three outer perianth leaves and the back inner one are wanting. The two front inner perianth leaves are represented each by a small scale, called a lodicule. The three inner stamens are wanting, and the front one of the three carpels. The three outer stamens are present, and have long delicate filaments so that the relatively large, versatile anthers hang out of the flower. The ovary, composed of the two back carpels, is one-celled, and contains one ovule. It has two large feathery stigmas.

Floral formula, $KO, C2, A3 + O, G^{(2)}$.

These small flowers are arranged in little spikelets combined into compound inflorescences which it is necessary to further explain. This can best be done by comparing them with the inflorescence of such a plant as Hyacinth.

FIG. 23.



In Hyacinth the flowers are arranged in a raceme, each arising in the axil of a bract, and having a second bract near the base of its pedicel. In the grasses also we get in the same way two bracts, called the inferior and superior paleae, enclosing each flower. These bracts, however, are bigger than the small flowers, the flowers are almost sessile, and each spikelet consists, as a rule, of only two or three, sometimes only

of one, flower. Also the lowest flowers do not develop, so that at the base of each spikelet we find a certain number of bracts; called glumes, from the axils of which flowers do not arise. Thus, in dissecting a spikelet of wheat, we find first two glumes, then three flowers, each enclosed by two paleae and each consisting of two hair-like lodicules, three large stamens with versatile anthers, and a pistil. Thus the inflorescence and the flower really correspond exactly to those of Hyacinth, but, being small and reduced, they are sometimes rather difficult to understand, though the structure as described above is sufficiently characteristic.

The inferior palea generally ends in a kind of spine, called the awn, which is particularly the case in Barley. The stigmas are long and feathery. As the ovary ripens the paleae adhere to it, and form a fruit known as a caryopsis. Inside the seed we find a quantity of food material known as endosperm, and in Wheat, etc., where such a useful property has been cultivated, this is particularly the case.

The inflorescences are generally exceedingly complex in this family. The spikelets, as above described, may be, as in Wheat, themselves sessile on a long axis, forming a compound spike; or, as in Oats, borne on slender, branched lateral branches, the whole forming a loose panicle. Again the spikelets may be monoecious, that is, some may consist entirely of staminate and others of pistillate flowers.

As examples of the Order, we may mention, in addition to the above, Dog's-tooth Grass, Moor Grass, Mat Grass, Melic Grass, Fescue Grass, Vernal Grass, which gives the odour to new-mown hay, Rye, Twitch, Spelt, Rice, Maize, Sugar-cane etc.

Characteristics of the Order Gramineae.

The stem is simple, round, and hollow except at the nodes.

The leaves have a ligule and a split sheath.

The flowers and inflorescence have the peculiarities described above.

Order Cyperaceae.

The Sedge family must be mentioned before leaving this group of Orders. It consists of marsh plants, intermediate between Rushes and Grasses. Sedges differ from rushes in that the perianth is either imperfect, or represented by 3-6 bristles or scales. They differ from Grasses in that they are stiffer, and that the stem is solid and often angular, with the sheath of the leaf closed round it. The superior palea is absent, so that each flower has only one, the inferior palea; the styles are not feathery and the glumes are brown, while in Grasses they are purple or green. Otherwise, the compound inflorescences consist of spikelets very similar to those of Grass.

Examples of the Order are, Galingale, Bog Rush, Club Rush, Bulrush, Cotton Grass, Sedge, the Egyptian Papyrus from which paper was made, etc.

Order Aroideae.

Lords and Ladies. *Arum maculata*.

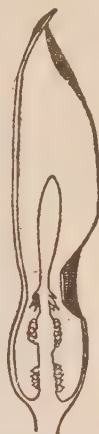
This plant is very common in woods and under hedges. It flowers in the spring. It has a tuber and heart-shaped leaves with long sheathing petioles, dark green and shiny, spotted with purple, sometimes with white veins. The inflorescence is a club-shaped spadix, partly enveloped in a large green sheathing bract, called a spathe. The upper end of the axis is club-shaped, yellow or purplish, without any flowers. Below this come a number of rudimentary flowers, terminating in hairs which point downwards. Next we find flowers each consisting of a few stamens, without any perianth, and finally at the base some consisting each of a single carpel, also without perianth. The abortive flowers act in a way precisely similar to the bars of a lobster trap. They allow an insect to pass down to the base of the inflorescence, amongst the fertile flowers, but prevent its return. The fruit (poisonous)

is a bright red berry, the collection of berries, after the spathe and leaves have died away, being very conspicuous. FIG. 24.

We might be tempted to consider this inflorescence as a single flower, but are prevented from doing so partly because the stamens are higher on the axis than the ovaries, and partly because in other similar plants the individual flowers are more complete.

In *Acorus*, the Sweet Flag, the flowers are perfect, each with six perianth segments, six stamens, and three carpels, on the usual monocotyledonous plan.

The White Arum, sometimes known as the Calla Lily, belongs to this order, and has the staminate flowers embedded in the club-shaped axis. The Lemnaceae or Duck-weeds are also very simple examples of the same family.



inflorescence
of Arum.

Characteristics of the Order Aroideae.

The Order is characterised by its small numerous monoecious flowers and by its peculiar inflorescence, with the sheathing spathe.

SUMMARY OF CLASSIFICATION OF THE ABOVE ORDERS.

CLASS MONOCOTYLEDONS.

Sub-class I. Petaloidae.

Series 1. Hypogynae.

Order Liliaceae.

„ Juncaceae.

Series 2. Epigynae.

Order Iridaceae.

„ Amaryllidaceae.

„ Orchidaceae.

Sub-class II. Nudiflorae.

Series 1. Glumflorae.

Order Gramineae.

„ Cyperaceae.

Series 2. Spadiciflorae.

Order Aroideae.

„ Lemnaceae.

CHAPTER VI.

DESCRIPTION OF TYPICAL EXAMPLES OF THE DICOTYLEDONS AND THEIR CLASSIFICATION.

THE DICOTYLEDONS are divided into three sub-classes:—

Sub-class I. **Apopetalae**.—Where the corolla consists of free petals.

„ II. **Gamopetalae**.—Where the corolla consists of united petals.

„ III. **Apetalae**.—Where the corolla is imperfect or wanting.

SUB-CLASS I.—**Apopetalae**.

The **Apopetalae** are divided into three Series:—

Series 1. **Thalamiflorae**.—Where the receptacle is conical and the flowers are hypogynous.

„ 2. **Disciflorae**.—Where the receptacle forms a disc and the flowers are hypogynous.

„ 3. **Calyciflorae**.—Where the receptacle is cup-shaped and the flowers are perigynous or epigynous.

Series 1. **Thalamiflorae**.

Order **Ranunculaceae**.

Buttercup. *Ranunculus bulbosus*.

This plant is a herb, with a swollen root-stock and secondary root. The leaves are both radical and cauline, simple,

but deeply and irregularly divided, especially the lower ones, with palmate veins.

FIG. 25.

The lower ones have long sheathing petioles, but as they go up the petiole becomes shorter and shorter till the leaves are nearly sessile. The inflorescence is a cyme. The flowers are golden yellow in colour and cup-shaped, with five sepals and petals, and numerous stamens and carpels. All the parts are free from one another. The sepals are reflexed, and soon drop off. At the base of each petal is a nectary. (See Fig. 26.) The fruit is a collection of achenes, each containing one seed consisting of a tiny



Buttercup.

embryo, surrounded by endosperm. Buttercup is exceedingly common in meadows, and flowers in early summer.

Floral formula, $K_5, C_5, A_{\infty} G$

A very common variation from the type is for the corolla to be either absent, as in *Clematis*, *Anemone*, etc.; or much reduced, e.g. the small tubular petals of *Hellebore*. In these cases the calyx is generally petaloid. The number of petals and sepals also varies. Thus *Clematis* has four sepals, *Anemone* six, *Hellebore* eight to ten petals, and *Baneberry*

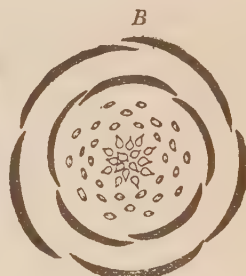
four. Clematis also differs from the type in having a climbing woody stem with opposite leaves. In Monk's Hood and Larkspur the flowers are irregular. The fruit of Baneberry is a berry, and of *Nigella* a capsule, and in many cases the fruit is a collection of follicles.

In *Anemone* the involucre of bracts below the flower should be noticed. Columbine has spurred petals. In Mousetail the receptacle lengthens very much after flowering, and in Clematis, popularly called Old Man's Beard, from the appearance of the fruit, the achenes develop long feathery awns as they ripen. The Lesser Celandine, when growing in damp places, reproduces itself by means of bulbils. As other examples, we may notice Rue, Pasque Flower, Globe Flower,

A FIG. 26.



A.—Vertical section of flower of Buttercup.



B.—Horizontal diagram of flower of Buttercup.

Marsh Marigold, Peony, Water Crowfoot, whose submerged leaves are cut into hair-like segments, etc. Most plants of the Order are acrid, and many are poisonous, *e.g.* Monk's Hood, whose root is sometimes mistaken for Horse Radish. The flowers of the Order very readily "double"—that is, their stamens become transformed into petals, as in Double *Ranunculus*, Bachelor's Button, Double Peony, etc.

Characteristics of the Ranunculaceae.

The plants are all herbs (except *Clematis*).

All the parts of the flower are free.

The stamens are numerous.

This Order is one of the largest, and is distributed over all the Temperate regions of the world.

Belonging to nearly allied Orders we have :—

1. Barberry, belonging to the Order Berberidaceae, which differs from the preceding in being a shrub, and in having only six stamens. There are six sepals and petals, and a single carpel. Common Barberry has fascicled leaves, which really belong to dwarf shoots, arising in the axils of spines, which are transformed leaves. The flowers are orange, and arranged in racemes. It is interesting to note that the stamens are irritable; to promote cross-fertilisation, they spring forward and close over anything touching them on the inside of their base.

2. Water-Lily, belonging to the Order Nymphaeaceae, which differs from the Ranunculaceae in having indefinite petals, like the stamens arranged spirally, and because the numerous carpels are rendered coherent by being buried in an outgrowth of the receptacle.

Order Papaveraceae.

Field Poppy. *Papaver rhoeas*.

The Common Poppy is an erect branched annual, with milky juice, from one to two feet high, covered by stiff hairs. It is found chiefly in corn-fields, and flowers all summer. The lower leaves are stalked and a good deal divided, the flowers large, showy, and solitary. Each has two hairy sepals, which drop off as the flower opens. The four petals, very much crumpled in the bud, are bright red except at the base, which is dark coloured. The stamens are numerous and free. The pistil consists of numerous united carpels, with a curious flat stigma. The ovary is one-celled, but divided nearly to the middle by projecting parietal placentas, and forms a capsule opening by pores and containing very numerous (32,000 !) small seeds.

Floral formula, $K_2, C_2 + 2A \infty G^{(\infty)}$.

FIG. 27.

Poppy



FIG. 28.



A.—Horizontal diagram of flower of Poppy.



B.—Vertical section of flower of Poppy.

The Greater Celandine has orange juice and only two carpels; as also *Eschscholtzia*, a Californian genus, where the receptacle forms a sheath to the base of the ovary, so that the flower is nearly perigynous. Yellow Glaucum, the Sea Poppy, or Horned Poppy, has a long pod-like capsule. The milky juice of the Opium Poppy is obtained by making gashes in the pericarp, and from it opium, laudanum, and morphia are manufactured, as also oil from the seeds.

Characteristics of the Papaveraceae.

The plants are herbs with milky juice.

Petals 4, regular.

Stamens ∞ .

Carpels united, with parietal placentation.

This order belongs chiefly to the North Temperate Zone.

Order Cruciferae.

Wallflower. *Cheiranthus cheiri*.

The Wallflower is a perennial herb, slightly woody at the base, a good deal branched, and covered with soft short hairs. The leaves are dark green, narrow and pointed, with entire margin, and nearly glabrous. The inflorescence is a raceme destitute of bracts. The flowers are rather large, brown streaked with orange, or entirely dark brown, and very sweet-scented. There is a distinct calyx and corolla, each consisting of four separate leaves arranged in a cross. There are six stamens, four long and two short (tetradynamous). At the base of the short stamens there are nectaries, which push them and the opposite sepals out, and cause the swellings, which may be observed from the outside. The pistil consists of two united carpels, as shown by the bilobed stigma. The style is very short, but the ovary long, consisting of two carpels joined by their edges, so that the placentas are parietal. The replum—a partition called false because it is only an outgrowth from the carpels—divides the ovary into two cells. After fertilisation the ovary lengthens very much,

and forms a siliqua. When ripe the two carpels split off from below upwards, leaving the seeds attached to the replum. The Wallflower has spread from Southern Europe into Britain, where it is now found wild in rocky situations, and on ruins in the neighbourhood of old gardens. It flowers through the spring and early summer.

Floral formula, $K2+2, C2+2, A2+2^2, G^{(2)}$.

FIG. 29.



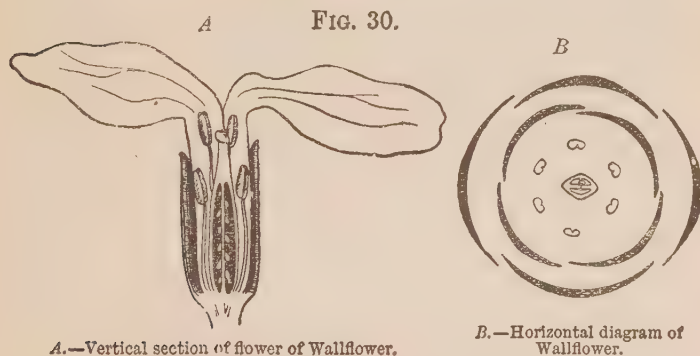
Wallflower.

There is a very strong resemblance amongst all the flowers of this Order, and it is said that none are poisonous. The chief differences are with regard to details concerning the fruit and seed. Thus in Shepherd's Purse the fruit is a silicula, broader than long. In Honesty it is much compressed parallel to the replum, which is therefore wide. In Candytuft, on the other hand, the fruit is compressed at

right angles to the replum, which is therefore very narrow. In Radish the siliqua is jointed.

To this Order belong the different kinds of Stock, Hedge Mustard, Rocket, Dame's Violet, Cabbage, Cauliflower, Turnip, Rape, Mustard, Penny-Cress, Woad, Sea-Rocket with fleshy leaves, Seakale, Horse-Radish, etc.

The structure of the flower presents some difficulty, and



A.—Vertical section of flower of Wallflower.

B.—Horizontal diagram of Wallflower.

some people have explained it on the theory that each whorl has four parts, two inner stamens, and two carpels being suppressed. A comparison with the following order renders it much more probable that the whorls are really of two parts each, and that the inner stamens have split and doubled themselves.

Characteristics of the Order Cruciferae.

The plants are herbs.

The inflorescence is a raceme without any bracts.

The petals are 4, in a cross.

The stamens are six, tetradynamous.

The fruit is siliquoid.

This Order is chiefly found in Temperate regions.

Order Fumariaceae.

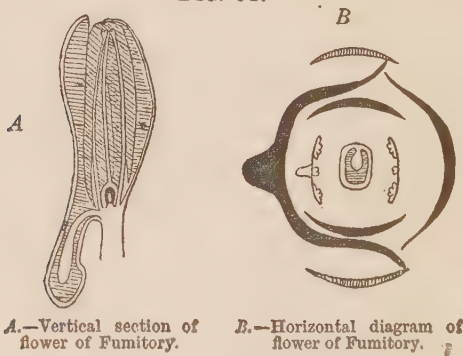
Common Fumitory. *Fumaria officinalis.*

This is a delicate, sometimes climbing herb, perfectly

glabrous, and pale green in colour. The leaves are much divided, with watery juice. It is a fairly common weed of cultivation in England, but is very variable in details. The flowers are small, white or red in colour, in dense racemes, which, however, lengthen as the flowering season, which lasts all summer and autumn, proceeds. Each flower has a short pedicel and a scaly bract, and consists of two sepals, four petals, four stamens, and two united carpels. One of the outer petals is swollen at the base, so as to make the flower irregular. It must be remarked that the two inner stamens are not in their natural position, but have split, and one half of each is united with each of the outer stamens, thus forming two groups of apparently three stamens each. Each group really consists of one whole and two half stamens, and though a cursory glance would lead one to suppose that the flower had six stamens, there are really-four.

Floral formula, $K_2, C_2 + 2, A_2 - 2 \text{ } G^{(2)}$.

FIG. 31.



The Yellow Corydal is another example of this Order, also the Dielytra of our greenhouse, which has both the outer petals gibbous.

Characteristics of the Order Fumariaceae.

The peculiar structure of the flower.
Especially of the stamens.

Order Resedaceae.

Wild or White Mignonette. *Reseda lutea*.

FIG. 32.

Mignonette is a herbaceous annual with alternate entire or lobed leaves. The small and irregular flowers are numerous in a raceme. The petals are greenish, and the upper part is much divided. The stamens are numerous and pinkish, inserted on a broad hypogynous disc. The pistil is composed of three united carpels, and it is a peculiarity that the ovary opens at the top long before the seeds are ripe.

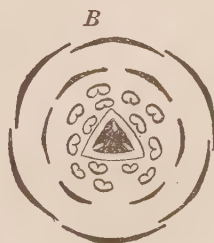


Wild Mignonette.

FIG. 33.



A.—Vertical section of flower of Mignonette.



B.—Horizontal diagram of flower of Mignonette.

The Order is a small one, confined to the Mediterranean

region, and represented in Britain by the Dyer's Mignonette, Cut-leaved Mignonette, and the White Mignonette.

Characteristics of the Order Resedaceae.

The structure of the flower as described above.

Order Violaceae.

Sweet Violet. *Viola Odorata.*

The Violet is a small perennial herb, with radical heart-shaped leaves, and also a few alternate, stipulate, cauline ones. It flowers in the hedge bottoms, etc., early in spring. The sepals are joined to the stem some distance above their base, and the

FIG. 34.



Sweet Violet.

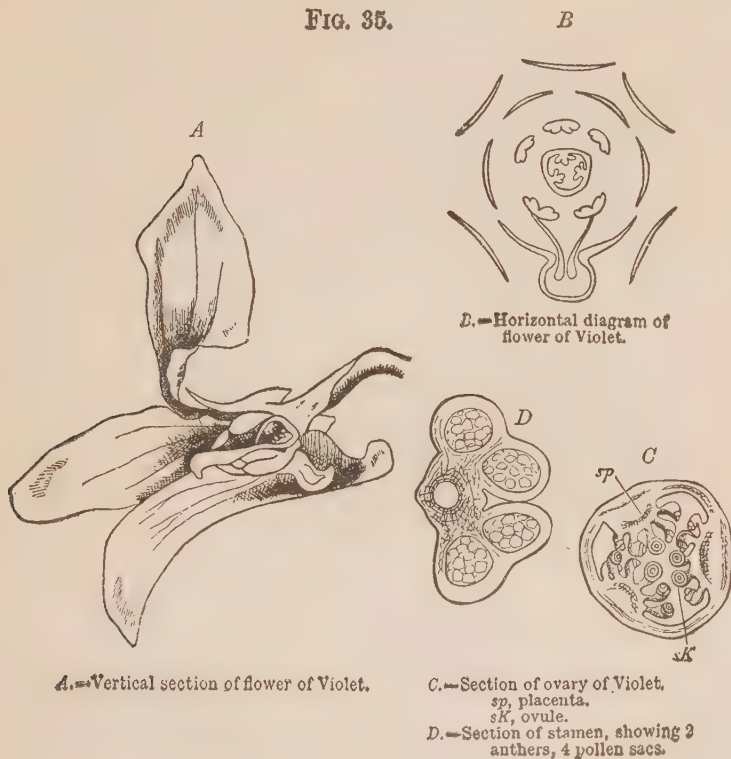
back ones are separated to make room for the pouch of the large back petal. The corolla is purple and irregular. The five stamens are almost sessile, each with two long, pale yellow anthers on the inner side, and the connective prolonged into a pointed bright orange tip. The two backstamens are spurred, the spurs being really nectaries which hang down into the pouch of the back petal, into which they drop the honey which they secrete. The pistil is composed of three united carpels, with parietal placentas. The curious bent style is hollow, and the stig-

matic surface is on the inside of the little lip. The fruit is a capsule. Besides these coloured flowers, which are specially adapted for cross-fertilisation, the Violet also produces in the autumn small green closed flowers, easily mistaken for the capsules, which are self-fertilised, and called cleistogamous.

Floral formula, $K_5, C_5, A_5, G^{(3)}$.

Other examples of the Order, which is very widely distributed all over the world, are Wood Violet, Marsh Violet, Pansy, etc. Some exotic species are trees and shrubs with almost regular flowers.

FIG. 35.



Characteristics of Order Violaceae.

Plants are herbs.

Flowers irregular, back petal pouched.

Stamens 5, connective prolonged beyond the anthers.

Placentas 3, parietal.

Order Caryophyllaceae.

Bladder Campion. *Silene inflata*.

This plant is a branched perennial with ascending stems, swollen at the nodes, and bearing long, pointed,

FIG. 36.



Campion.

The placentation is free central, but traces of partitions can be distinguished at the bottom of the ovary. The fruit is a capsule.

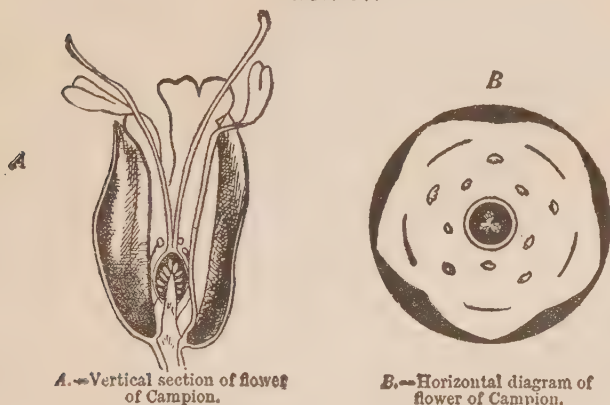
Floral formula, $K(5), C5, A5 + 5, G^{(3)}$.

In very many plants of this Order the sepals are free, or nearly so. The number of parts also varies in different

opposite decussate leaves. The colour is grayish green, and the plant is glabrous. It occurs all over Britain, flowering in summer. The large white flowers are arranged in loose cymes. There is a united calyx, much inflated—whence its name—which becomes nearly globular, marked with very distinct veins. The white petals are free and deeply notched, with a scale where the limb joins the claw. There are ten hypogynous stamens and a united pistil with three styles.

specimens. In many the inner whorl of stamens is suppressed, and in some, the corolla is absent. In *Lychnis* the axis is lengthened between the calyx and the corolla, and some species of the genus, *e.g.* *Campion*, are dioecious. Other

FIG. 37.



examples are the different varieties of Pinks and Carnations, often doubled under cultivation, *Stellaria*, Soapwort, Pearlwort, etc.

Characteristics of the Order Caryophyllaceae.

Plants are herbs.

Stems are swollen at the nodes.

Leaves are entire and opposite decussate.

Flowers are regular, generally with the petals deeply notched.

Stamens 10, sometimes fewer.

This Order is found chiefly in Temperate regions.

Order Polygalaceae.

Milkwort. *Polygala vulgaris*.

This is a very little herb, common in meadows, with curious, irregular, characteristic flowers. There is a good

deal of variation in size and colour, but the flowers are generally bright blue or pink. At first sight they might be mistaken for the papilionaceous flowers described later, but further examination reveals a different structure. There are five sepals, three small and greenish, and two called the wings, relatively large and bright coloured. Within these there are only three small petals. The front petal is the largest, and is keel-shaped, with a little crest. The eight stamens cohere into a little tube which is united to the front petal, so as to give the impression of a united corolla. The anthers are only one-celled. The pistil is formed by the union of two carpels, and has a curious hooded stigma. The fruit is a capsule, and is enclosed between the wings, which persist.

Order Malvaceae.

Common Mallow. *Malva sylvestris*.

Common Mallow is a biennial, with ascending stems covered by long, spreading hairs. It is found on roadsides, etc., and flowers in summer. The leaves are petiolate and stipulate, palmately lobed. The flowers are rather large, purplish pink in colour, given off in the axils of the leaves. Some bracts just below each flower form the characteristic epicalyx. The sepals are valvate and the petals contorted in the bud. The petals have each a short claw united to the tube formed by the united filaments of the stamens. The stamens are very much branched above, and end each in a single anther. There are about ten carpels arranged round a prolongation of the axis. The fruit is a schizocarp, each division containing one campylotropous seed.

Floral formula, $K(5), C(5), A(5) \infty G^{(\infty)}$.

All the plants of this Order are inclined to be mucilaginous. The Cotton plant belongs to it, the cotton fibre being derived from long hairs on the seeds. Lamp-oil is also made from the

FIG. 38.



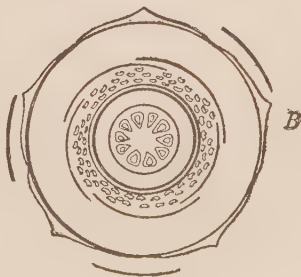
Common Mallow.

A

FIG. 39.



A.—Vertical section of flower of Mallow.



B.—Horizontal diagram of same.

crushed seeds, and the remnant yields oil-cake. Other examples are Hollyhock, Marsh Mallow, Abutilon now so common in greenhouses, etc.

Characteristics of the Order Malvaceae.

Plants are herbs or shrubs.

Flowers regular, sepals valvate, petals contorted.

An epicalyx.

Stamens forming a tube below, much branched above.

The Order is distributed over the North Temperate and Tropical Zones.

Order Hypericineae.

Common St. John's Wort. *Hypericum perforatum*.

The Common St. John's Wort is a herb found in woods,

FIG. 40.



St. John's Wort.

hedge bottoms, etc., and flowers in summer and autumn. It has sessile, entire, oblong leaves, marked by clear spots, which are oil-glands, whence the name. The flowers are bright yellow, with five petals and sepals. The outer whorl of stamens is suppressed, being represented by staminodes in some exotic genera. The inner stamens are branched, and give rise to five bundles of stamens. The pistil consists of three united carpels, and the fruit is a capsule.

Floral formula, $K_5, C_5, A_0 + 5 \varphi G^{(5)}$.

Tea plant belongs to an allied non-British order, as also does the Camellia.

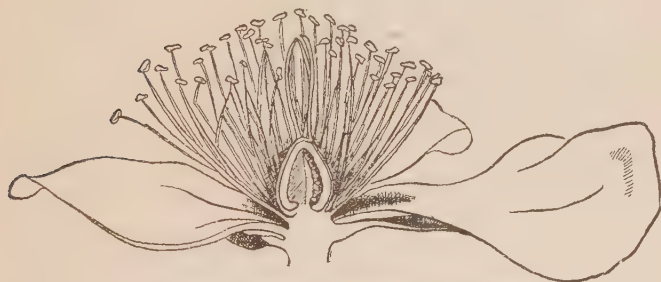
Characteristics of Order Hypericineae.

The structure of the flower.

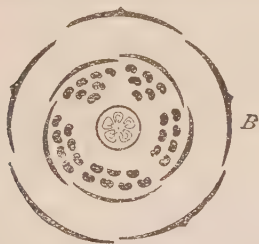
Especially the five bundles of stamens.

FIG. 41.

A



A.—Vertical section of flower of St. John's Wort.



B.—Horizontal diagram of flower of St. John's Wort.

Series 2. **Disciflorae.**

Order Geraniaceae.

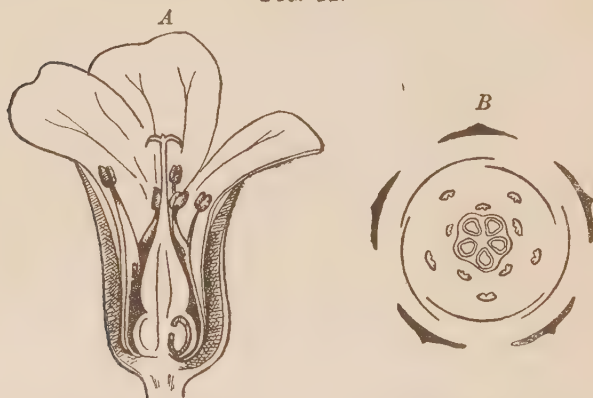
Herb Robert. Wild Geranium. *Geranium robertianum*.

Herb Robert is a small, much-branched annual, flowering all through the summer. It grows in waste places, open woods, etc. The leaves have three divisions, each of which is pinnately lobed, and are stipulate. As they grow old they turn red, and have a disagreeable smell when rubbed. The flowers are small, and consist of five pointed hairy sepals, five pink

entire petals, ten stamens, and five carpels, which surround a central prolongation of the axis, called the carpophore. The stem forms a glandular disc. Each carpel contains two ovules, and when ripe splits away from the carpophore from below upwards, the fruit being thus a schizocarp, composed of five divisions or cocci.

Floral formula, $K_5, C_5, A_5 + 5, \bar{G}^{(5)}$.

FIG. 42.



A.—Vertical section of flower of Wild Geranium.

B.—Horizontal diagram of flower of Wild Geranium.

In *Erodium* five of the stamens are transformed into staminodes. Notice that the ten stamens are not all erect at the same time. *Pelargonium* has an irregular corolla, the back petal having a spur, by means of which it is attached to the pedicel. There are a very large number of British Wild Geraniums, many of them very handsome, such as the Meadow Crane's Bill.

Characteristics of the Order Geraniaceae.

Plants are herbs.

Leaves simple and stipulate.

Pistil consisting of five carpels arranged round a beak-like carpophore.

The Orders *Linaceae*, *Oxalideae*, *Balsamineae*, and *Tropaeoleae*, are very closely allied to the *Geraniaceae*,

though they have no disc. They differ amongst themselves in the following points:—

In the Linaceae, to which the Flax belongs, five of the stamens are transformed into staminodes. The flower is regular, the fruit a capsule, and the leaves simple, sometimes with, sometimes without, stipules.

The Oxalideae have regular flowers and ten stamens, connate at the base. The fruit is a capsule or berry, with numerous seeds. The leaves are compound and exstipulate. Ex.: Wood Sorrel.

The Balsamineae have irregular corollas and only five stamens. The fruit is a capsule, opening by elastic valves. Ex.: Impatiens, the Wild Balsam.

The Tropaeoleae have irregular flowers, with eight stamens and three carpels, forming a schizocarp. Ex.: Nasturtium.

Series 3. Calyciflorae.

Order Rosaceae.

Wild Rose. *Rosa canina*.

Wild Rose is a climbing shrub, very common in hedges and thickets, flowering about June. Its branches are covered by prickles. The leaves are delicate, compound pinnate, with

FIG. 43.

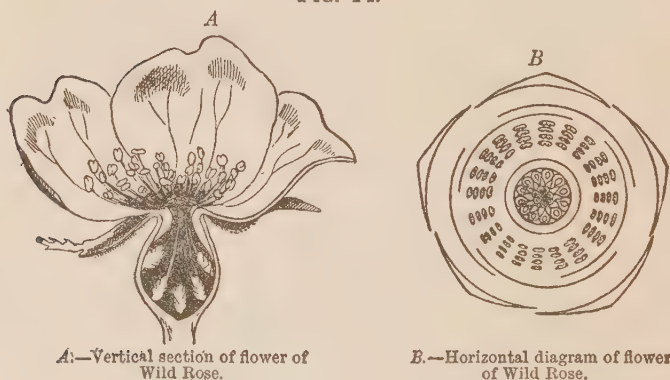


Wild Rose.

leafy stipules. The flowers are large and lovely. The stem ends in a deep cup, nearly closed at the top, with the carpels in the hollow, and the sepals, petals, and stamens on the edge of the cup, so that the flowers are perigynous. The five sepals are green, irregularly toothed and reflexed. The petals, also five, are obcordate, of a delicate pink and white colour. The carpels are numerous, each with a one-seeded hairy ovary, and a long style projecting through the narrow opening of the hollow receptacle. Each carpel forms an achene, but the fruit is spurious, called a hip, as the receptacle also becomes fleshy. The flowers have a very sweet smell, and, under cultivation, become double.

Floral formula, $K_5, C_5, A_\infty \overline{G}^\infty$.

FIG. 44.



The various plants belonging to this large and important Order differ a good deal as to the form of the receptacle and as to their fruit. The Order is accordingly subdivided as follows :

1. *Roseæ*.

The receptacle is hollow, enclosing numerous carpels. The fruits are achenes, enclosed in the receptacle which becomes fleshy, the whole hip being a spurious fruit. The flowers are large. To this division belong all the various kinds of Roses.

2. Spiraeaceae.

The receptacle is flat and open, with only five carpels inserted on it. The fruit is dry. The leaves are much divided, and the flowers small in a complex inflorescence. Ex.: Meadow Sweet, Spiraea, etc.

3. Amygdaleae.

The receptacle is hollow, enclosing a single carpel. This forms a drupe, while the receptacle drops off, so that the fruit is true. Ex.: Almond, Plum, Cherry,

4. Dryadeae.

In this division the axis is prolonged into the hollow receptacle, so that the flowers approach very closely to the Ranunculaceae. There is generally an epicalyx. The carpels are numerous. Sometimes the receptacle becomes fleshy, and the carpels form dry fruits, as in Strawberry; sometimes the carpels alone become fleshy, as in Raspberry; sometimes both are dry, as in Potentilla. Other examples are Blackberry, Water Avens, etc.

5. Pomeae.

The receptacle is deeply hollow and encloses from one (hawthorn) to five (apple) carpels. It becomes fleshy, forming a spurious fruit called a pome. The carpels may form achenes, as in the core of apple, or may become hard, as in hawthorn. Ex.: Pear, Quince, Medlar, Mountain Ash, etc.

6. Sanguisorbeae.

The receptacle bears only one carpel, and becomes hard as the fruit ripens. The plants in this division differ more than any others from the type. They may be monoecious as in Salad Burnet. Sometimes they have no corolla, as in Lady's Mantle, which also has its parts in fours. In the Great Burnet there are only four stamens. Agrimony has a spike of pentamerous yellow flowers, with numerous stamens.

Characteristics of the Order Rosaceae,

Plants are herbs, shrubs, or trees.

Leaves are stipulate, generally compound pinnate.

Flowers are regular and pentamerous.

All the parts of the flower are free.

Stamens are generally numerous.

The flowers of this Order differ from those of Ranunculaceae chiefly in the form of the receptacle, which renders the flowers perigynous instead of hypogynous.

Order Leguminosae.

Sweet Pea. *Lathyrus odoratus*.

This plant has trailing annual stems, which climb by means of the tendrils into which the upper leaflets of the compound

FIG. 45.

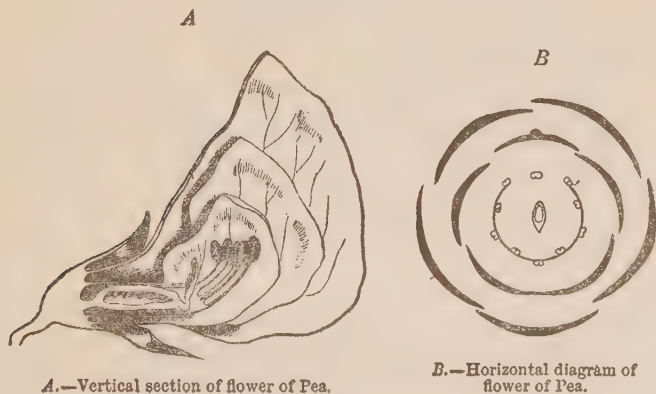


Pea.

pinnate leaves are modified. It flowers in the middle of summer. The leaves bear two large leafy stipules. The

flowers are variegated and bright-coloured. The united calyx is irregular, with five teeth. The five petals are free except the two front ones. The corolla is very characteristic, being known as the butterfly, or papilionaceous corolla. The back petal is large and erect, and is called the "standard"

FIG. 46.



the two side petals are called the "wings," and interlock with the "keel," which is formed of the two united front ones. Notice the delicate claws of the wings and keel, and the way in which the whole front of the flower moves down, as if on a hinge, when pressed. There are ten stamens, nine united in a tube round the pistil, and one free. The pistil consists of only one carpel, with a one-celled ovary and a bent style, hairy at the top. The fruit is a pod containing several seeds,

Floral formula, $K(5), C5, A(5+5), G^1$.

In an important division of this Order the flowers are regular, with free, often numerous, stamens, much longer than the small perianth. To this division belong many varieties of *Acacia* and *Mimosa*. In the Australian *Acacias* the leaf is reduced to a mere spine, and the leaf-stalk is expanded into

a phyllode. Other examples of the Order are Bird's-foot Trefoil, Clover, Medick, Scarlet-Runner and other Beans, all the Vetches, Laburnum, Indigo, Liquorice, Lentil, etc.

Characteristics of the Order Leguminosae.

Plants are herbs, shrubs, or trees.

Leaves compound pinnate, with stipules.

Flowers (with exceptions) papilionaceous.

One carpel forming, as a rule, a pod.

Order Crassulaceae.

The plants of the Order have fleshy entire leaves, arranged spirally, often in rosettes. The inflorescence is generally cymose and the flowers have the formula.

$$K_n C_w A_n \text{ or } A_n + n G^{(n)}, \text{ where } n = 3 - 30.$$

Examples House-leek, Stone-crop, Crassula, etc.

Order Saxifragaceae.

In this Order we find perigynous or epigynous flowers, with four or five parts in each whorl, and generally a double whorl of stamens. The carpels, usually two or three in number, are very characteristic, being connate, that is, united below and free above. Examples are Syringa, Gooseberry, Currant, Hydrangea, many varieties of Saxifrage, including Grass of Parnassus, which has the five stamens opposite the petals transformed into glandular staminodes.

Order Umbelliferae.

Cow Parsnip. Hogweed. *Heracleum sphondylium*.

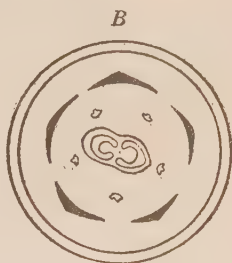
This is a tall, coarse, hairy, branched annual, very common in hedges and meadows, and flowering in summer. The stems are hollow, grooved, and covered by stiff hairs. The leaves are pinnate, and divided into five or seven broad segments. The leaf-stalk forms a large sheath. The flowers are small and white, collected into compound umbels, with an involucre of deciduous bracts at the base of each umbel. The calyx consists of five small teeth, and the corolla of five

small, notched, white petals, the outer ones of which are larger than the inner, especially in the outside flowers of the umbel. Five stamens alternate with the petals, but soon drop off. The inferior ovary is formed of two carpels, and is nearly spherical, with a disc at the top, formed by the bases of the two styles. It is marked by alternate ridges and grooves

FIG. 47.



A.—Vertical section of flower of Cow Parsnip.



B.—Horizontal diagram of flower of Cow Parsnip.

(coreae and vittae), and glands open into the grooves, whose aromatic oil gives the strong smell to the plant. In this plant the grooves only extend half-way down the ovary. The fruit is a schizocarp, separating into two cocci, each of which contains one seed.

Floral formula, $K_5, C_5, A_5, G_{(2)}$.

The flowers of this Order are very constant, and are often only distinguished by details concerning fruit and seed, etc. In Pennywort the leaves are round, in Sea Holly stiff and spinous, in Samphire fleshy, in Fennel dissected. Other examples are Carrot, Celery, Parsley, Caraway, Anthriscus, etc.

Characteristics of the Order Umbelliferae.

Plants are herbs, but generally very large for herbs.

Inflorescence an umbel or compound umbel.

Stamens 5, epigynous.

Styles 2, forming a disc.

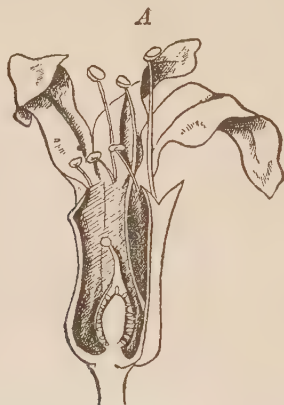
This Order is widely distributed, but is particularly common in Southern Europe and Temperate Asia.

Order Lythraceae.

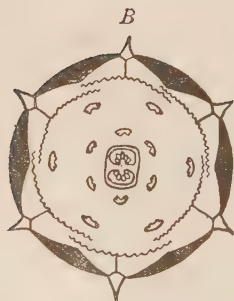
Purple Loosestrife. *Lythrum salicaria*.

This plant has a perennial root stock, and stout annual erect stems two to three feet high. It grows in damp places

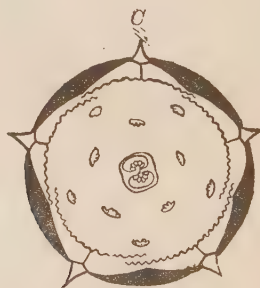
FIG. 48.



A.—Vertical section of flower of Purple Loosestrife.



B.—Horizontal diagram of flower of Purple Loosestrife.



C.—Diagram of the 5-partite variety.

and flowers in summer. The leaves are sessile, entire, lanceolate, and opposite. The pinkish purple flowers form large dense spikes, with leafy bracts. The flowers are perigynous, with sepals, petals, and stamens at the edge of a cup. They

have an epicalyx, so that there appear to be two whorls of six sepals each, six petals, and twelve stamens, differing in length. Three different lengths are found, but only two lengths in any one flower; thus, one flower has six long and six medium stamens, another six medium and six short, and so on. The pistil is composed of two carpels.

Floral formula, $K_6, C_6, A_6 + 6, G^{(2)}$.

The only other British examples are Hyssop Lythrum, a similar but smaller plant, and Water Purslane. A variety of the Common Loosestrife is sometimes found with five divisions in each whorl.

Characteristics of the Order Lythariaceæ.

The structure of the flower.

Especially the stamens of different lengths.

Order Onagraceæ.

Willow-Herb. *Epilobium hirsutum*.

FIG. 49.

Willow-Herb is a tall, perennial herb, with clasping, lanceolate, undivided leaves and regular pink flowers, round growing in damp situations, and flowering in summer. The whole plant is softly hairy. The flowers are epigynous and tetramerous, with a very long inferior ovary, which grows into a long capsule opening by four valves to set free the numerous hairy seeds.

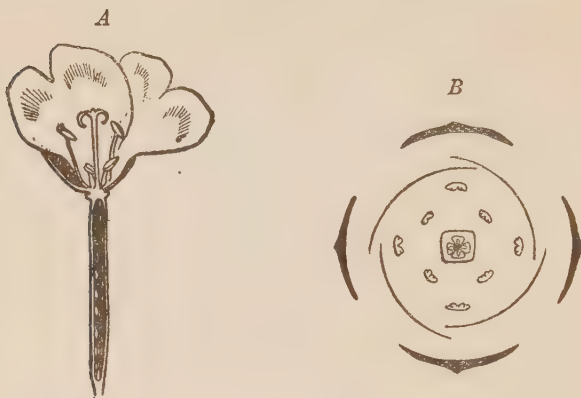


Willow-Herb.

Floral formula,
 K_4, C_4, A_4 or $A_4 + 4, G_{(4)}$.

In *Fuchsia* the calyx is petaloid and forms a tube, and the fruit is a berry. The *Enchanter's Nightshade* has two parts in each whorl instead of four. There are many different

FIG. 50.



A.—Vertical section of flower of Willow-Herb.

B.—Horizontal diagram of flower of Willow-Herb.

species of Willow-Herb, varying in size and colour. Evening Primrose also belongs to this Order.

Characteristics of the Order Onagraceae.

Flowers are usually tetramerous.

A very long inferior ovary, forming

A long capsule opening by four valves.

SUB-CLASS II.—Gamopetalae.

The **Gamopetalae** are divided into two Series:—

Series 1. **Hypogynae**, with a superior pistil and hypogynous flowers.

Series 2. **Epigynae**, with an inferior pistil and epigynous flowers.

Series 1. **Hypogynae.**

Order Primulaceae.

Primrose. *Primula vulgaris*.

Primrose is a perennial herb, with a secondary root. The stem is much shortened, so that the leaves form a radical rosette. They are obovate in shape, with an irregularly indented margin and pinnate veins, which project on the under

FIG. 51.

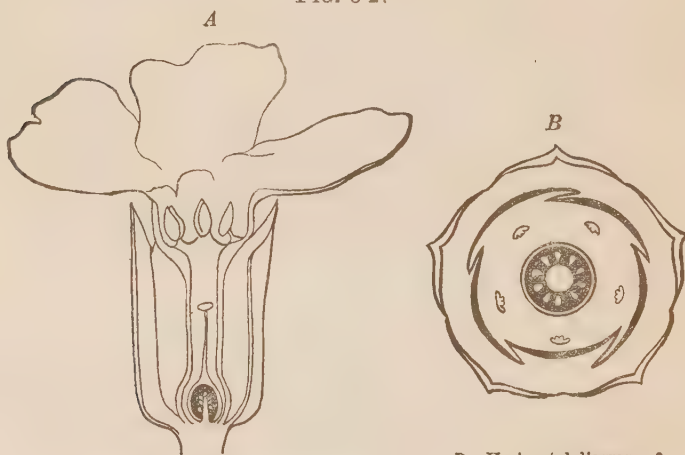


Primrose.

side. The inflorescence is really an umbel, like that of cowslip, but the main axis is here so short that it does not appear above the ground, except in abnormal cases, so that the flowers emerge each on its own separate pedicel. The flower is pentamerous, the calyx of united sepals. The corolla is also united and is tubular below, with spreading heart-

shaped lobes, pale yellow except at the base of the lobes, where it is orange. The stamens are attached to the corolla tube, opposite the corolla lobes. This is explained by supposing that an intermediate whorl, represented in an allied Order by staminodes, has been suppressed. The pistil is superior, with free central placentation and a simple style. The fruit is a capsule. In some flowers, called by the country folk "thrum-eyed," the stamens are placed at the top of the tube, and the style is shorter; in others, the "pin-eyed," the

FIG. 52.



A.—Vertical section of flower of Primrose.

B.—Horizontal diagram of flower of Primrose.

pistil is as long as the tube, and the stamens are placed low down. The Primrose is very abundant on banks and in woods throughout Britain. It flowers about April.

Floral formula, $K(5), C(5), A0+5, G^{(6)}$.

Besides Cowslip, Oxlip, Primula, Polyanthus, Auricula, Water Violet, etc., whose resemblance to the Primrose at once strikes the eye, we may mention as other examples Pimpernel, the Shepherd's Weather-Glass, a widely-known herb with a short-tubed orange corolla, very sensitive to variations in

light and temperature ; Cyclamen, with reflexed corolla and an underground tuber ; Yellow Loosestrife, with long trailing stems, bearing flowers in the axils of the leaves.

Characteristics of the Order Primulaceae

Plants are herbs.

Corolla tubular, generally with spreading lobes.

Stamens epipetalous, opposite corolla lobes.

Placenta free central.

Sea Lavender and Thrift are maritime herbs belonging to the nearly allied Order Plumbagineae. They have small crowded flowers surrounded by numerous bracts. They differ from the Primulaceae in having five styles and a single basal ovule instead of numerous ovules.

Order Labiatae.

White Lamium, or White Dead Nettle. *Lamium album.*

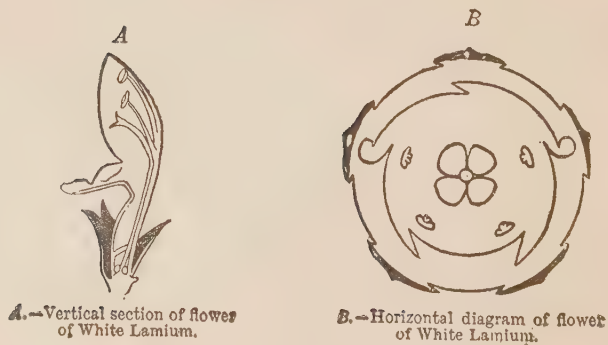
This plant, which has no other relation to Nettle than a resemblance between the leaves, is a herb flowering nearly all the year round, but especially in summer, and very common in hedge bottoms, etc. The stem is square and ascending, bearing ovate, coarsely hairy, toothed leaves arranged in pairs which cross one another. The inflorescence, called a verticillaster, is peculiar. In the axil of every leaf is situated a small cyme of nearly sessile flowers, and, since the leaves are opposite, we get thus a circle of flowers at every node. The calyx and corolla are both irregular and united, the corolla being two-lipped, much longer than the calyx, and easily dropping. The stamens are four in number, epipetalous, two short and two long (didynamous). The anthers are twisted to lie in a straight line instead of side by side, which makes them measure less across, and fits them to the insects which visit the flower. They are black, with white hairs. The pistil is superior, and consists of two united carpels. Each cell of the ovary divides, however, completely into two, so that the fruit consists of four achenes. The long style arises from the base of the ovary, between

FIG. 53.



White Lamium,

FIG. 54.



A.—Vertical section of flower
of White Lamium.

B.—Horizontal diagram of flower
of White Lamium.

the four divisions, and ends in a forked tongue just below the upper lip of the corolla.

Floral formula, $K(5), C(5), A4, G^{(2)}.$

In Sage only two stamens are found, and the connective is so much developed that it becomes much more conspicuous than the short filament. The anthers are widely separated, and one, carried down into the tube of the corolla, is abortive. In some plants of the Order the corolla is scarcely longer than the calyx, and in many there is only one lip. Examples are Mint, Lavender, Basil, Thyme, Marjoram, Balm, Hyssop, Rosemary, Ground Ivy, Bugle, Prunella, etc.

Characteristics of the Order Labiatae.

Plants are herbs.

Corolla irregular, labiate.

Stamens 4, epipetalous, didynamous.

Style basal.

Stem square, bearing opposite decussate leaves.

Order Scrophulariaceae.

Foxglove. *Digitalis purpurea.*

Foxglove (the folk's, *i.e.* the fairy's glove) is a tall, erect, perennial herb. It has ovate, coarsely hairy, radical leaves on long stalks. The flowering axis also bears leaves below, and ends in a raceme of irregular, large, showy flowers. It grows in woods and shady places, and flowers about the middle of summer. The purple corolla is tubular, somewhat two-lipped, paler inside, but the front lip spotted with purple, and hairy. The stamens are didynamous, inserted on the corolla, and twisted so as to lie under the back lip. The Foxglove differs from the preceding Order in having a two-celled ovary and a terminal style. The fruit is a capsule.

Floral formula, $K(5), C(5), A4, G^{(2)}.$

This is a large Order, and presents important variations. In Snapdragon the irregular corolla is called personate because it is supposed to resemble a *persona* or mask. The tube is

almost closed by a process of the lower lip. Toadflax is also personate, and is in addition spurred. Sometimes a monstrous form, called a Peloria, is found, which becomes

FIG. 55.



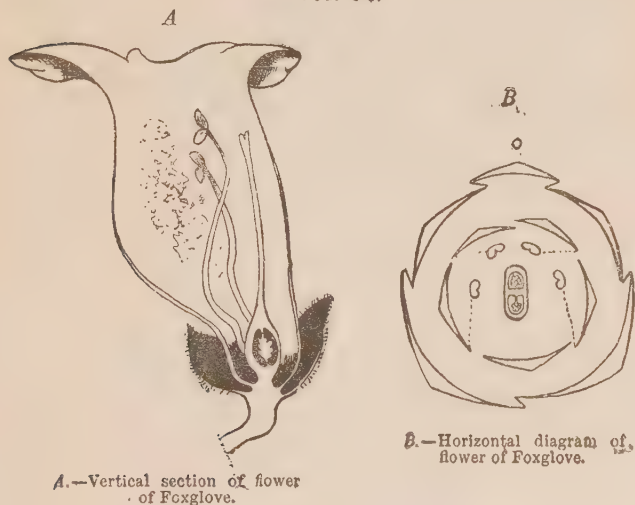
A.—Foxglove inflorescence.

B.—Foxglove leaf.

regular by having five spurs and five lips. In *Veronica* the tube is very short, and the lobes flat and nearly equal, so that the corolla is rotate, and there are only two stamens.

Mullein has a ringent corolla, with a very short tube and five woolly stamens. Speedwell is a Veronica. Other examples are Calceolaria, Figwort, Musk, Rattle, Eyebright, etc. The two last named are partly parasitic, usually on grass roots.

FIG. 56.



The Order Orobancheae is quite similar to the foregoing, but the plants are entirely parasitic, *e.g.* the Broomrape, parasitic on the Leguminosae.

Characteristics of the Order Scrophulariaceae.

Plants are herbs.

Corolla is irregular.

Stamens usually 4, epipetalous didynamous, sometimes 2 or 5.

Style terminal, and ovary 2-celled.

Leaves usually alternate.

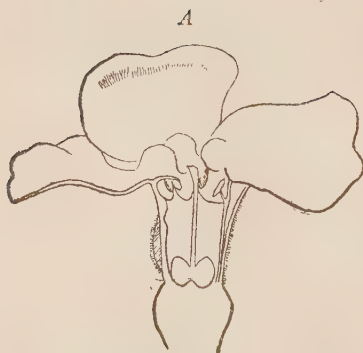
This Order is common in Temperate regions. It is closely allied to several Tropical Orders, such as the Bignoniaceae, Acanthaceae, etc.

FIG. 57.

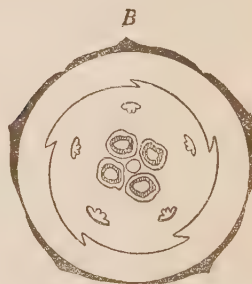


Forget-me-not.

FIG. 58.



A.—Vertical section of flower of Forget-me-not.



B.—Horizontal diagram of flower of Forget-me-not.

Order Boraginaceae.

Forget-me-not. *Myosotis palustris*.

The Boraginaceae, of which Forget-me-not may be taken as the type, have a four-lobed ovary and basal style like the Labiatae. They are, however, distinguished by the regular, generally five-lobed, corolla, and stamens equal in number to the lobes of the corolla, also by the alternate leaves, etc. Plants of this Order are characterised in addition by the scaly appendages of the petals at the top of the corolla tube, and by being coarsely hairy. Examples are Comfrey, Borage, Heliotrope, etc.

Order Ericaceae.

Heather. *Erica cinerea*.



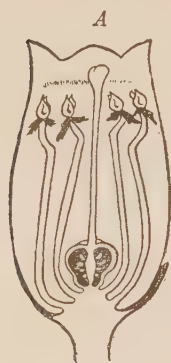
FIG. 59.

Heather.

The Ericaceae have regular tubular flowers, with twice as many stamens as petals, not epipetalous. The anthers open by pores at the top. The carpels are opposite the petals and

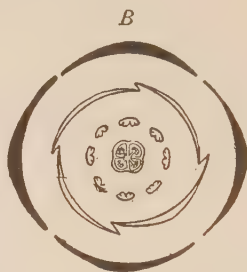
united. The fruit is sometimes a capsule, sometimes fleshy. The chief British varieties are Ling and Heather.

Floral formula, $K(n), C(n), An + n, G^{(n)}$.



A.—Vertical section of flower of Heather.

FIG. 60.



B.—Horizontal diagram of flower of Heather.

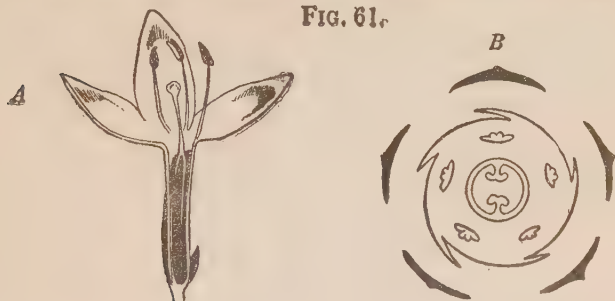
The Orders Apocynaceae, Gentianaceae, Solanaceae, Convolvulaceae are nearly allied, and all have the same

Floral formula, $K(5), C(5), A(5), G^{(2)}$.

The Apocynaceae have for the chief British specimen the Periwinkle, a herb found in many parts of England, but probably not truly wild. It is a trailing evergreen plant, with wiry stem, milky juice, and opposite, entire, shiny leaves. The flowers are large, blue, and solitary. The corolla has five contorted lobes, and forms a tube, on which are inserted the five stamens. The pistil is superior, formed from two carpels, which are free at the base, and which ripen into two separate fruits, but which are united into a peculiar hour-glass-shaped stigma. This curious pistil is the great characteristic of the Order, which is very poisonous. Examples are Oleander, and the Greater and Lesser Periwinkle. From the milky juice of some tropical species indiarubber is produced. Stephanotis, Asclepias, Hoya, etc., are tropical plants belonging to nearly allied Orders.

The *Gentianaceae*, too, are herbs with opposite, entire, glabrous leaves. The juice, however, is not milky, and the flowers, instead of being solitary, are arranged in cymes.

FIG. 61.



A.—Vertical section of flower of Centaury.

B.—Horizontal diagram of flower of Centaury.

The carpels are completely united and form a syncarpous fruit. To this Order belong the various species of *Gentian*, also pink *Centaury*, *Yellow-wort* with connate leaves, *Buck Bean*, etc.

The *Solanaceae* have flowers of similar structure to the last. The Order is characterised by the geminate leaves and by the peculiar inflorescence. This is really cymose, but the bracts, from the axils of which the flowers spring, instead of

FIG. 62.



A.—Vertical section of Potato flower.

B.—Horizontal diagram of Potato flower.

being at the point from which the flower springs, are displaced upwards, so as to be immediately under the flower, together with the bracteole borne by the peduncle. Most plants of the Order are poisonous, though in some, *e.g.* *Potato*, the

underground part is wholesome. The fruit is usually a poisonous berry. Sometimes the calyx persists round it, as in Winter Cherry, where it becomes red and inflated.

To this Order belong also Nightshade, Tomato, Petunia, Henbane, Thorn Apple, etc.

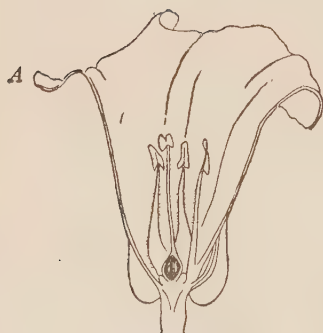
The **Convolvulaceae** are climbing plants with milky juice. The flower has contorted aestivation. The fruit is a capsule

FIG. 63.

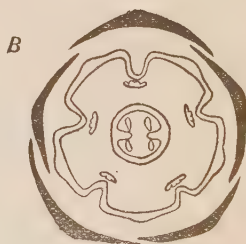


Bindweed.

FIG. 64.



A.—Vertical section of flower of Bindweed.



B.—Horizontal diagram of flower of Bindweed.

or a berry. Examples: Greater and Lesser Bindweed, Sweet Potato, etc.

The *Cuscutae*, sometimes taken as a separate Order, sometimes included under the *Convolvulaceae*, are similar on the whole, but are parasitic. Their leaves accordingly are not developed, and their stems are modified into tendrils which twine round the branches of the host. The small flowers are arranged in bundles. Various species of Dodder are parasitic on Hop, Nettle, Flax, Clover, and Gorse.

FIG. 65.

Series 2. *Epigynae*.

Order Compositae.

(1) Daisy. *Bellis perennis*.

Common Daisy is a small herb, with a secondary root and radical, spatulate (spoon-shaped) leaves. The flower head, which at first sight looks like a single flower, is really a capitulum of small florets, at the end of a long stalk. The stem and leaves are both covered by short hairs. The florets are of two kinds:—

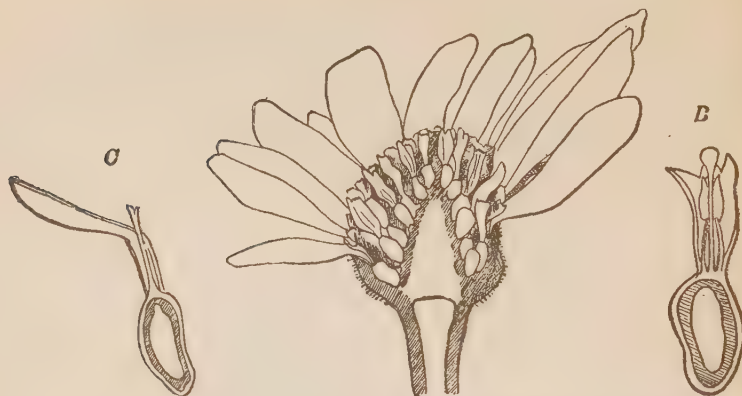
1. Yellow disc florets.
2. White ray florets.

In both kinds of florets the calyx is represented only by a few hairs. The disc florets are tubular and regular, with five lobes. The ovary is inferior, and there is a long style, so that the forked stigma, when fully grown, projects from the tube. The five stamens are united by their anthers (syngenesious), which form a tube round the pistil. The



Moon Daisy.

FIG. 66. A



A.—Section of capitulum of Moon Daisy. B.—Section of a disc floret.
C.—Section of a ray floret.

FIG. 67.



Section of capitulum of Dandelion.

ray florets have an irregular ligulate (strap-shaped) corolla, and no stamens. The pistil is like that of a disc floret, but shorter. In both florets the fruit is an achene. The capitulum is surrounded by dark green imbricated bracts.

(2) Dandelion. *Taraxacum officinale*.

Dandelion must be compared with Daisy. Note the runcinate leaves which give the name to the plant, and its milky latex. The florets are all alike, and all ligulate, like the ray florets of Daisy, but they are all perfect, containing each five syngenesious stamens. The calyx is represented by

FIG. 68.



A.—Vertical section of floret of Dandelion.



B.—Horizontal diagram of floret of Dandelion.

a pappus, which is distinct before fertilisation, and which develops greatly after, surmounting the achenes with a stalked brush of hairs which helps to float them through the air, and thus to distribute them.

(3) Thistle. *Carduus lanceolatus*.

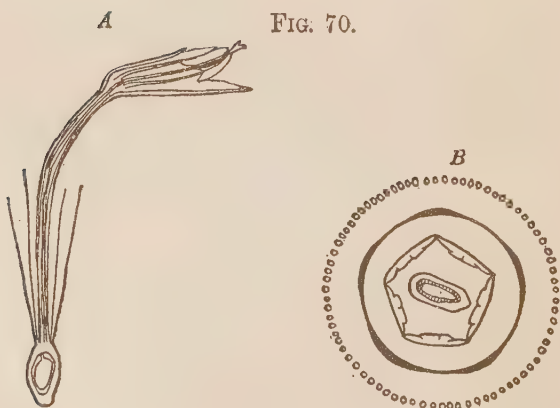
Note here the shape of the capitulum, and the bracts amongst the flowers, in addition to those forming the involucre. The florets are all alike, and all perfect, but here they are all tubular, having a similar structure to the disc florets of Daisy.

FIG. 69.



Section of capitulum of Thistle.

FIG. 70.



A - Vertical section of floret of Thistle. B. - Horizontal diagram of floret of Thistle.

The Compositae are divided into two sub-orders :—

1. **Tubuliflorae**, in which either all or some of the florets are tubular, *e.g.* Thistle and Daisy.
2. **Liguliflorae**, in which the florets are all ligulate, *e.g.* Dandelion.

In the Liguliflorae the florets are always all perfect, but amongst the Tubuliflorae they may be all perfect, as in Thistle; or the disc florets perfect and the ray florets pistillate, as in Daisy; or the disc florets perfect and the ray florets neuter, as in Sunflower and Corn Cockle; or the disc florets staminate and the ray florets pistillate, as in Marigold; or finally, all the florets of one head pistillate and all those of another staminate, as in Everlasting.

This is the largest and most important of all the Orders, and it contains between eight and nine thousand species, scattered over the whole world. In some species, *e.g.* Yarrow, the flower heads so closely simulate single flowers, that it is necessary to look carefully.

Examples of the Order are :—Hemp Agrimony, Butterburr, Colt's-foot, China Aster, Golden Rod, Groundsel, Artemisia, Yarrow or Milfoil, Tansy, Sunflower, Burdock, Carlina, Knapweed, Corn Cockle, Safflower, Globe Thistle, consisting of one-flowered capitula in large heads, Everlasting, Chamomile, Lettuce, Salsify, Chicory, etc.

Characteristics of the Order Compositae.

Plants are herbs.

Inflorescence a capitulum, composed of small florets.

Stamens 5, sygenesious.

Ovary one-celled, inferior, with one erect ovule.

The Compositae form a well-marked order. The only other which might be confounded with it is the Order Dipsaceae, to which Teasel belongs. The Dipsaceae, however, have a bilabiate corolla, only four stamens, the calyx often bristly, the ovule suspended in the ovary, and the bracts amongst the florets spiny.

The "doubling" of Compositae must be distinguished

FIG. 71.



Bluebell.

from what is usually known as doubling. A double Daisy is formed by the change of the tubular florets of the disc into ligulate florets, not by any change in the stamens.

Order-Campanulaceae.

Bluebell. Harebell.

Campanula rotundifolia.

All the plants of this Order have regular tubular, bell-shaped flowers, with a five-lobed corolla. The five stamens are not epipetalous, but are connate at the base. The pistil is inferior, and consists of three united carpels, giving rise in fruit to a capsule containing numerous seeds. The plants have milky juice. Canterbury Bell is another example.

Floral formula, $K(5), C(5), A(5), G_{(3)}$.

FIG. 72.



A.—Vertical section of flower of Bluebell.



B.—Horizontal diagram of flower of Bluebell.

Order Caprifoliaceae.

This Order has a very similar structure to the last. The flowers are, however, often irregular, and the stamens are epipetalous. The fruit is a berry. The plants are trees or shrubs, with opposite leaves.

Floral formula, $K(5), \underbrace{C(5), A(5)}, G_{(2-5)}$.

FIG. 73.



A.—Vertical section of flower of Honeysuckle.



B.—Horizontal diagram of flower of Honeysuckle.

Examples with a regular corolla are Elder, and Guelder Rose, in which the outer flowers of the umbel, or in cultivated specimens all the flowers, are barren. With an irregular corolla we have Honeysuckle, Snowberry, etc.

SUB-CLASS III.—Apetalae.

The **Apetalae** are divided into two Series :—

Series 1. **Hypogynae**, with a superior pistil and hypogynous flowers.

Series 2. **Epigynae**, with an inferior pistil and epigynous flowers.

Very many plants of this sub-class have their small imperfect flowers collected into close spikes, known as catkins or amentae. In a typical catkin a

flower arises in the axil of a bract, and its stalk bears two bracteoles, in the axil of each of which arises a flower with two bracts. In practice this is generally more or less simplified.

FIG. 74.



Diagram of a typical catkin.

Series I. Hypogynae.

Order **Ulmaceae**.

English Elm. *Ulmus campestris*.

FIG. 75.



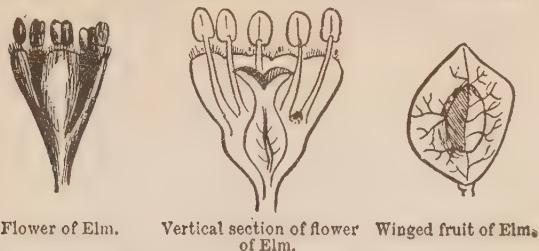
Branch of Elm
with catkins.

Elm is a large tree of somewhat irregular form. The leaves are broadly ovate and nearly sessile, toothed, oblique at the base, rough on the upper and downy on the under side. The flowers are borne in clusters in the axils of the leaves, but before the leaves unfold. They are small, but perfect, having perianth, stamens, and carpels. Only one cell of the ovary matures, and this forms a winged fruit known as a Samara, by the development of a membrane, which is deeply notched.

Floral formula, $P(5), A_5, G^{(2)}.$

This is a small Order, almost confined to the Temperate

FIG. 76



Flower of Elm.

Vertical section of flower
of Elm.

Winged fruit of Elm.

Zone. The only other British representative is the Wych Elm.

Characteristics of Order Ulmaceae.

Plants are trees.
Ovary two-celled.

Flowers are perfect.
Fruit a Samara.



FIG. 77.

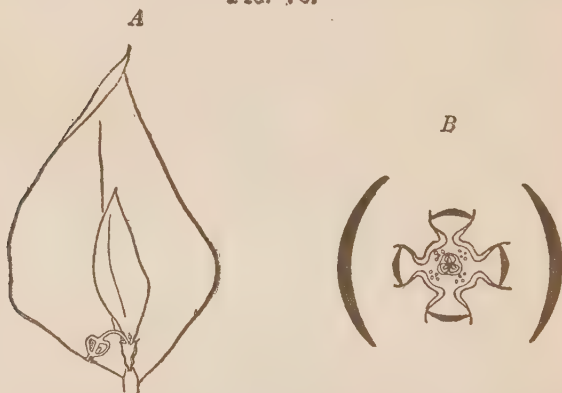
Common Sun Spurge.

Order Euphorbiaceae.

Common Sun Spurge.

Euphorbia helioscopia.

Sun Spurge is an erect annual, six to eight inches high. It is a very common weed, with milky juice, flowering all through the summer. The leaves are light green, ovate or orbicular, on a short stalk, the margin minutely toothed. The inflorescence is somewhat complicated. A small cluster of flowers is developed in the axil of each bract. This cluster is enclosed in a tubular involucre, which has four crescent-shaped glandular appendages, and consists of five staminate and one pistillate flower. Each staminate flower consists of a single stamen, and each pistillate flower of three united carpels, on

FIG. 78.

A.—A cyathium of Sun Spurge with its own bract, and a lower bract.

B.—Horizontal diagram of Cyathium, showing the pistillate flower, the staminate ones, the involucre with its four appendages, and two bracts.

a long curved stalk. The ovary is three-celled, and the style three-cleft. Such a cluster, called a cyathium, might easily be taken for a single flower. It must, however, be observed that there is a joint at the base of each stamen and pistil, showing where they join their pedicel, and in exotic Orders a perianth is developed at this point. The fruit is a schizocarp.

The inflorescence is compound and cymose. The main axis terminates in a cyathium, but below it, each in the axil of

a bract, branches are given off, which themselves after branching terminate in cyathia. At the first branching there are five or six branches, but fewer as we go up, generally two at each of the final branchings, each in the axil of a bract, with the terminal cyathium between them.

This is chiefly a Tropical Order, and varies greatly in aspect. The other British genus is *Mercurialis* (Dogs' Mercury), found abundantly in woods. Here the juice is not milky, and each staminate flower consists of several stamens, and both staminate and pistillate flowers have a perianth. The Tropical species also are generally inconspicuous and weed-like, though the milky juice of the South American *Siphonias* supplies large quantities of indiarubber. *Poinsettia* and *Jatropha* are cultivated for the sake of their bright red bracts. Box belongs to a closely allied Order.

Characteristics of the Order Euphorbiaceae.

The structure of the ovary and fruit distinguishes the plants of this Order from all other unisexual plants.

Order Salicineae.

Common Sallow. *Salix caprea*.

This is a tall shrub or bushy tree, growing in the neighbourhood of streams, and flowering early in spring, before the leaves are out. The leaves are ovate, greyish green, somewhat wrinkled, covered underneath with hairs, and provided with rather large stipules. The imperfect flowers are collected into rather short, silky, gray catkins, which are found on very short dwarf shoots. At the base of each catkin there are a few scaly bracts. The plants are dioecious—that is, all the staminate catkins are on one plant, and all the pistillate on another. The flowers arise each in the axil of a bract, which is covered behind by long silky hairs. A staminate flower consists of two stamens and an imperfect perianth; a pistillate flower of a dimerous pistil and an imperfect perianth.

The ovary is one-celled, and contains numerous ovules, which ripen into seeds covered by silky hairs.

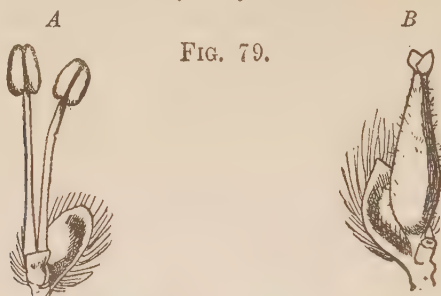


FIG. 79.

A.—Staminate flower of *Salix*.B.—Pistillate flower of *Salix*.

In some specimens the stamens are more numerous than in *Salix*. The various species of Willow and Poplar, and the Aspen, belong to this order.

Characteristics of the Order Salicineae.

Flowers are arranged in catkins.	Pistil superior, dimerous, one-celled.
Plants are dioecious.	Fruit a capsule.
Perianth reduced to a scale.	The median flower is developed.

Series 2. Epigynae.

Order Corylaceae.

Common Hazel. *Corylus avellana*.

The Common Hazel is a tall shrub or small tree. It grows in woods and thickets, and flowers in early spring before the leaves are out. The leaves are broadly ovate or orbicular, toothed, and downy on both sides. The flowers are arranged in staminate and pistillate catkins, which, however, are both found on the same tree (monoecism). The staminate flowers have no perianth. Each consists of four stamens branched into eight, in the axil of a bract. Comparing this with the general diagram, we have here as in Willow the median flower and its bract, without any branches. The staminate catkins are from one and a half to two inches long, and arise several

together in drooping clusters. The pistillate flowers arise two together, and are the two lateral flowers, the median flower being suppressed. They are surrounded by the primary bract and their own bracteoles, and consist of a

FIG. 80.



Twig of Hazel, with a staminate and a pistillate catkin.

FIG. 81.



A.—Pistillate catkin.



B.—Staminate flower of Hazel.

rudimentary perianth surrounding a pistil composed of two carpels. The ovary is two-celled, but only one cell contains ovules, two in number, of which, as a rule, only one develops into a seed. The stigmas are red. The pistillate catkin is short, and surrounded by bud scales, so that it looks just like a bud, except for the red stigmas projecting at the top. The fruit is a nut. After fertilisation the inner bracteoles belonging to the flowers develop very much, and form a leafy involucre known as the husk.

Examples of this order are Hornbeam, where the fruit is ribbed and has a three-lobed investment and 4-10 stamens, and where flowering takes place after the leaves are open; also Copper Hazel.

Characteristics of the Order Corylaceae.

Plants are trees.

Flowers are arranged in catkins.

Plants are monoecious.

Pistil inferior, with a bilocular ovary.

Fruit a nut surrounded by a husk.

Two lateral pistillate flowers develop.

Order Cupuliferae.

The Oak. *Quercus robur*.

The Oak is a spreading tree with particularly dense and lasting wood. The leaves are simple and pinnately

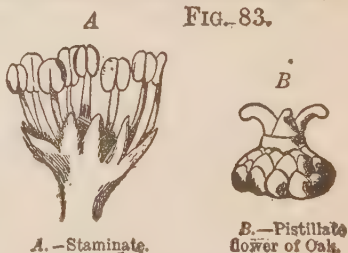
FIG. 82.



Branch of Oak, with leaves and catkins.

lobed. Flowering takes place in early spring, immediately after the unfolding of the leaves. There are two kinds of catkins borne on the same tree. The staminate catkins are slender and pendulous, with one staminate flower, the central one, in the axil of each bract, without any branch flowers or bracteoles. The bracts are small, and the staminate flowers consist of a variable number of stamens surrounded by a perianth of from 5 to 7 lobes. The pistillate catkins are similar, containing a variable number of pistillate flowers, each in the axil of its own bract, but surrounded by an involucre of bracteoles, called a cupule. The ovary has two chambers, with two ovules in each chamber, but only one seed is formed, the fruit being a nut invested by the cupule, which develops greatly after fertilisation.

In Beech the pistillate catkin consists of two flowers only; and the fruit is composed of two nuts surrounded by a single cupule, which is covered by bristles and, when ripe, splits open by four valves. To the same Order belong Cork Oak and Copper Beech.

*Characteristics of the Order Cupuliferae.*

Plants are trees.

Flowers in catkins.

Plants monoecious.

Perianth of several segments is present.

Pistil inferior with a trilocular ovary

Fruit a nut surrounded by a cupule.

The median pistillate flower only is developed.

CLASS DICOTYLEDONS.

SUB-CLASS I.	SUB-CLASS II.	SUB-CLASS III.
Apopetalae.	Gamopetalae.	Apetalae.
SERIES I.	SERIES I.	SERIES I.
Thalamiflorae.	Hypogynae.	Hypogynae.
ORDER.	ORDER.	ORDER.
Ranunculaceae.	Primulaceae.	Ulmaceae.
Berberidaceae.	Plumbagineae.	Euphorbiaceae.
Nymphaeaceae.	Labiateae.	Salicineae.
Papaveraceae.	Scrophulariaceae.	SERIES II.
Cruciferae.	Orobanchaceae.	Epigynae.
Fumariaceae.	Boraginaceae.	ORDER.
Resedaceae.	Ericaceae.	Corylaceae.
Violaceae.	Apocynaceae.	Cupuliferae.
Caryophyllaceae.	Gentianaceae.	
Polygalaceae.	Solanaceae.	
Malvaceae.	Convolvulaceae.	
Hypericineae.	SERIES II.	
SERIES II.	Epigynae.	
Disciflorae.	ORDER.	
ORDER.	Compositae.	
Geraniaceae.	Dipsaceae.	
Linaceae.	Campanulaceae.	
Oxalideae.	Caprifoliaceae.	
Balsamineae.		
Tropaeolaceae.		
SERIES III.		
Calyciflorae.		
ORDER.		
Rosaceae.		
Leguminosae.		
Crassulaceae.		
Saxifragaceae.		
Umbelliferae.		
Lythriaceae.		
Onagraceae.		

It need hardly be said that a knowledge of the plants described above can only be acquired by careful observation of the plants themselves. The following scheme for the description is appended as an assistance in such observation.

Scheme for Description of a Flowering Plant.

The Root.—Kind, shape.

The Stem.—Kind, growth, shape, colour, hairs, branching, internal appearance.

The Leaves.—Position, arrangement, leaf-stalk, stipules, veins, division, shape, margin, apex, colour, hairs, texture.

The Flower.—Arrangement (inflorescence), kind, general appearance, peduncle, bracts.

Calyx.—Duration, number, union, position, shape of whole calyx, shape, colour, etc., of sepals.

Corolla.—Describe as calyx.

Androecium.—Number, union, position, filament, anthers.

Pistil.—Number, union, position, stigma, style, ovary, placenta, ovules.

Seed.—Testa, endosperm, embryo.

Fruit.—Kind, appearance.

Aestivation.—Calyx, corolla.

Floral Formula.

Floral Diagrams.—Vertical, horizontal

Classification.

Time of Flowering.

Situation.

It must be remembered in using any scheme for plant description that the actual plant is the important thing. Schedules and schemes must be made to fit plants, not *vice versa*. Special peculiarities not provided for in a general scheme are the very things to be particularly noted.

PART II.

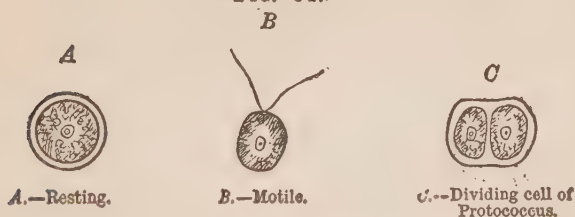
DESCRIPTION OF SOME TYPICAL NON-FLOWERING
PLANTS OR CRYPTOGAMS

CHAPTER I.

PROTOCOCCUS. HAEMATOCOCCUS PLUVIALIS.

PROTOCOCCUS is the simplest green plant known. If we observe a drop of rain water which has stood for some time, as for example water from the gutters of a roof, we shall probably find it green in colour. On examining such a drop under the microscope it will be seen that the green colour is due to a number of small, round, green bodies, floating in the water. Each of these is a distinct plant, perfect as far as it goes, though with its general business of life reduced to the simplest possible terms. This plant is often known by the name of Protococcus (*protos*=first; *coccus*=germ).

FIG. 84.



It consists of a small round mass of a clear, colourless, jelly-like substance, called protoplasm (*plasma*=material), which is interesting in that it is found to be the only really living substance there is—plants and animals alike all consisting essentially of this. Though in itself clear, it is generally loaded with granules of food and of waste material; and though in itself colourless, it may be coloured by a variety of colouring matters.

In the case of *Protococcus* the protoplasm contains drops of oil and little grains of starch, and is green in colour, owing to the presence of what is called chlorophyll (*chloros*=green, *phulon*=a leaf). Sometimes there is a red colouring matter in addition to the chlorophyll, and a variety of *Protococcus* which has only red colouring material gives the colour to the "red snow" of the Alps. A small round body, called the nucleus, may with some difficulty after treatment be brought into view lying in the protoplasm.

Such a round mass of protoplasm is generally found surrounded by a tough little sac of a colourless material known as cellulose, which forms what is called the cell-wall. But this is a non-essential part, as speedily appears. As one watches the slide, the probability is that similar little green bodies will be seen moving rapidly about, swimming across the field of the microscope, and vanishing from view unless they are quickly followed. These are the motile forms of *Protococcus*. A tinge of iodine added to the water checks their activity, so that their structure can be observed (*see* 84, *B*). They can then be seen to consist, like the resting forms, of a rounded mass of protoplasm, stained green by chlorophyll, but this time without any cell-wall. There is a clear spot at one end, from which proceed two little threads of protoplasm called cilia (*cilium*=a hair), which by their rapid vibration act on the water like oars, and move the plant about with great rapidity.

Intermediate forms between resting and motile *Protococcus* may sometimes be observed, and it is found that the motile forms arise by division from the resting, and that they subsequently, surrounding themselves by a cell-wall and drawing in their cilia, pass over into the resting condition. Fresh *Protococci*, either motile or resting, are constantly arising by division of the original one into two or four (*see* 84, *C*), which afterwards separate one from another.

Protoplasm is, then, the only essential part of a living organism. Each separate individual mass of it is called a cell.

So far we have been describing only the appearance and

structure of Protococcus. Facts relating to appearance, form, and structure make up Morphology (*morphe* = form, *logos* = speech). Those relating to mode of life and uses of the different parts belong to Physiology (*phusis* = nature). We must now go on to consider the physiology of Protococcus.

Protococcus collects and grows in any rain water exposed to air. The question is :—

(1) How does it get there?

(2) How does it continue to live and grow, being there?

With regard to (1), it is found that Protococcus in the resting form, protected by its cell-wall, can bear being very thoroughly dried, and yet recover itself when again in water. When, therefore, pools containing it dry up, it forms a fine dust, which is distributed by the air, and revives on again reaching water.

With regard to (2), it is found that Protococcus can only live—

At suitable temperatures.

In sunlight.

When supplied with food.

In the presence of a certain amount of oxygen, necessary for breathing.

At low temperatures Protococcus ceases to grow or move, but can recover even after having been frozen, if not for too long a time. On the other hand, it is immediately killed by a temperature approaching boiling-point. It grows best at a temperature of 70° to 80° F.

Before saying how Protococcus gets its food, it is necessary to say something about what it will need.

Most substances with which we are familiar, *e.g.* lime, chalk, fat, etc., can be resolved by chemists into simpler constituents. They are therefore called compounds. There are, however, a certain number of substances in the world which no one has, at least as yet, been able to resolve into anything else, and which are called accordingly elements. Such are many

metals,—gold, silver, iron, lead, etc. Living bodies are compounds, and the greater part of them is made up of six elements, viz :—

Carbon,	Symbol C,	familiar to us in charcoal and blacklead.
Oxygen,	„ O,	} Colourless gases, O and N making up air.
Nitrogen,	„ N,	
Hydrogen,	„ H,	
Sulphur,	„ S,	familiar as brimstone, a yellow crystalline solid.
Phosphorus,	„ P,	a pinky, waxy solid,

It must be clearly understood that a compound substance is quite unlike the elements out of which it is built up. Thus red rust—a compound of the two elements iron and oxygen—is totally unlike either the metal iron or the gas oxygen.

Protoplasm is a very complicated substance, and is not thoroughly understood by the best chemists. It consists of a combination of a substance called proteid with a little fat, and with small quantities of mineral salts. Analysis shows that proteids contain all the six elements—carbon, oxygen, nitrogen, hydrogen, sulphur, and phosphorus, the last two in small quantities only ; also that fat consists of carbon, oxygen, and hydrogen, without any nitrogen. The cellulose of the cell-wall consists of carbon, oxygen, and hydrogen, but has less carbon in proportion than fat.

It is evident, then, that the food of *Protococcus* must supply it with the six elements—carbon, oxygen, nitrogen, hydrogen, sulphur, and phosphorus, and with some mineral salts in addition.

Protococcus lives in rain water, which is water pure except for the substances which it has dissolved in falling through the air. Water itself (H_2O) consists of hydrogen and oxygen. In falling through the air it takes up carbon-dioxide gas (CO_2), which is composed of carbon and oxygen ; small quantities of ammonia (NH_3) composed of nitrogen and hydrogen ; also air and small quantities of various mineral salts, which contain sulphur and phosphorus, such as the sulphates and phosphates of sodium, always present as fine dust in ordinary air.

Thus all the requirements of *Protococcus* are met, including that of oxygen to breathe. It must be noticed that *Protococcus* cannot take up food quite in the elementary form, for it does not make use of the free nitrogen of the air dissolved in the water, but that its food is supplied to it in the form of the very simplest compounds, water (H_2O), carbon dioxide (CO_2), and ammonia (NH_3), each containing only two elements. The plant is able to build up these very simple compounds into the complicated substance of its own protoplasm. To enable it to perform this piece of work, which is too difficult for the best chemists, it must be supplied with energy, in the form of a certain degree of warmth, and especially in the form of sunlight, which, as stated above, is essential to the life of the plant.

It is a very remarkable fact that the protoplasm of a living cell in the presence of sunlight, and by aid of its chlorophyll, can build itself up out of the simplest compounds, viz. water, carbon dioxide, and ammonia, with small quantities of mineral salts.

PRACTICAL WORK.

Examine water coloured green by *Protococcus* under the high power ($\frac{1}{8}$ in. or $\frac{1}{5}$ in.).

Observe motile and resting forms, and make out the points described above. If the water has been previously exposed to warm sunlight, motile forms are pretty certain to appear, and probably cells in process of division, but this latter process is more readily seen by taking some of the green coating from the bark of trees (*Protococcus Viridis*).

Stain with iodine to check the rapid movement of the motile cells, and observe the cilia. Any grains of starch will at the same time turn blue. (Test for starch.)

By pressure on the coverslip the cell-wall may be burst, and the protoplasm squeezed out. Add potash, and the protoplasm dissolves, leaving an empty sac.

Treat some of the cells with Schultze's solution, and the cell-wall will be stained violet. (Test for cellulose.)

CHAPTER II.

YEAST. TORULA. SACCHAROMYCES CEREVISIAE.

Morphology.

If a drop of Yeast be spread out on a slide, and examined under the highest power available, it is found to consist of a watery fluid, containing a great number of small organisms, even smaller than those described in the last chapter. They consist, like Protococcus, each of a single cell, *i.e.* of a little mass of protoplasm, surrounded by a cell-wall. The protoplasm in this case, though granular, is colourless; there is no chlorophyll. In the middle a clear space may be observed. This is the vacuole, and is filled by the watery fluid, cell sap, which saturates the whole cell. A nucleus may also be brought into view by careful staining.

Reproduction.

Under favourable circumstances Yeast grows and reproduces itself very rapidly, and in a very simple manner. A swelling appears at one side of a cell; this increases, forming a bud; the swelling is followed by a constriction, and the bud, after remaining for some time in contact, entirely separates from the original cell, to which it is exactly similar. During rapid growth the bud may itself bud before separating, and thus whole strings of cells may arise, which, however, are all separated in course of time. This process is known as reproduction by gemmation or budding. It evidently requires plentiful supplies of food. If these fail, new cells are formed in a different manner. The protoplasm of a cell becomes divided, and rounded off into four little masses, which after a time acquire cell-walls of their own and burst the mother cell-wall and escape. They are called ascospores.

Physiology.

With regard to the mode of life of Yeast :—

In the first place Yeast, like *Protococcus*, can stand a good deal of drying, and is very often present as fine dust in the air. This explains why it is necessary to keep preserves, etc., perfectly air-tight, as otherwise Yeast cells would enter, and the preserve would “work.”

Secondly, it is found by experiment that Yeast is, unlike *Protococcus*, altogether independent of light.

Thirdly, that it requires a higher temperature than *Protococcus* for rapid growth, though, like *Protococcus*, it can recover from severe cold and is killed by boiling.

When we come to the question of food, we find that Yeast is incapable of taking in its food in the very simple forms which satisfy *Protococcus*. The experiments of M. Pasteur have shown that in the simplest substance available as food for Yeast, the necessary carbon, oxygen, nitrogen, and hydrogen are already combined into one substance, ammonium tartrate $\{(NH_4)_2C_4H_4O_6\}$. Yeast cells have some constructive energy, for even ammonium tartrate is much less complex than protoplasm, but they are in this respect much behind *Protococcus*. This difference must be associated with the want of chlorophyll, and the growth in absence of sunlight.

Yeast is able to grow in a solution containing ammonium tartrate and a few salts, but in order to flourish it also requires sugar.

The effect of Yeast cells on sugar is to decompose or ferment it, splitting it up into carbon dioxide and alcohol (=spirit of wine). It is the formation of carbon dioxide out of sugar which makes Yeast useful in bread-making. Carbon dioxide is, as before stated, a gas; and, bubbling through the dough, it causes the bread to “rise.” On the other hand, Yeast is useful in brewing because of the

FIG. 85.



A.—Yeast cell.



B.—Budding.



C.—Formation of Ascospores.

alcohol it produces. The carbon dioxide and alcohol formed almost exactly account for the sugar used, so that the Yeast cells appear to get little benefit from their labours. The fact seems to be, however, that the cells begin by taking a little oxygen from the sugar for their respiration, and that this, like putting a match to powder, causes a kind of explosion in the rest of the sugar. Probably the fermentive action has been increased by long cultivation. Similar actions on the part of similar plants probably give rise to fermentations leading to putrefaction and to disease in many other cases.

Classification.

Yeast and Protococcus are two of the very simplest plants. They differ from the simplest animals in the following points:—

- (1) They are capable of building up their own substance out of much simpler food. Animals require their food ready made.
- (2) Their cells are provided with a cellulose envelope, which is not present in animal cells.
- (3) On the whole, they spend their energy in growth and division, while animals spend theirs largely in movement.

Protococcus is the representative of the green plants or Algae, Yeast of those without chlorophyll, which are called Fungi. The great difference is that green plants, by aid of their chlorophyll, can, in the presence of sunlight, build up their own substance out of simpler materials than the Fungi. In this respect, therefore, we have a series in which the Fungi are intermediate between the green plants and the animals. Both Algae and Fungi require oxygen to breathe, though only in small quantities, the respiration of plants being much less active than that of animals. Yeast can, if necessary, get its oxygen by decomposing sugar.

Yeast and Protococcus belong, evidently, to the lowest group of the Vegetable Kingdom, the Thallophytes, plants distinguished as having no differentiation into stem and leaves.

PRACTICAL WORK.

Examine a drop of growing Yeast, diluted with water, under the highest power you possess.

Observe the cell-wall, protoplasm, vacuole, budding, and strings of cells, as described above.

Add staining fluid. Notice that the cell-wall does not stain, the protoplasm stains deeply, and the vacuole faintly.

By pressure on the coverslip burst the cell-wall, squeeze out the contents, and dissolve them by means of potash.

Take dry German Yeast. Suspend it in water so as to wash it. Let it stand, and pour away the liquid. Spread the deposit over fresh-cut potato slices, and keep moist. Ascospores can sometimes be observed after eight or nine days.

Take six test-tubes, and fill each about half full of growing Yeast diluted with water. Label them A, B, C, D, E, F. Place A in a warm light place, B in an equally warm dark place, C in a very cold light place, D in a very cold dark place. To F add a little sugar, and place E and F side by side. After two days compare the results to verify the statements as to growth made above.

Notice the bubbles of gas given off by a warm sugary fluid containing rapidly growing Yeast, and also the alcoholic smell.

CHAPTER III.

THE PROPERTIES OF PROTOPLASM

SINCE Protococcus and Yeast consist, essentially, simply of Protoplasm, the various powers which they exhibit may be recapitulated as the properties of Protoplasm. Thus:—

(1) Protococcus and Yeast can absorb their food from the surrounding water.	Protoplasm is absorptive.
---	---------------------------

(2) Protococcus and Yeast require oxygen for their respiration.	Protoplasm is respiratory.
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(3) Protococcus and Yeast convert food material into their own substance by various chemical changes known as digestion or constructive metabolism.	Protoplasm can digest, or is constructively metabolic.
---	--

(4) Chemical changes also go on in these plants, leading to the breaking down of their substance into starch, oil, etc., which are secreted or stored up for future use.	Protoplasm can secrete, or is destructively metabolic.
--	--

(5) Since these plants may continue to take in food without increasing in size, they must get rid of, or excrete, substances of no further use to them.	Protoplasm can excrete.
---	-------------------------

(6) The movements of motile *Protococcus* are due to rapid contractions of its cilia.

Protoplasm is contractile.

(7) Such movements are due to no external cause, but only to the inherent vitality, known as the automatism or self-movement of the plant.

Protoplasm is automatic.

(8) Though *Protococcus* moves of its own accord, its movements may be affected by an external cause; as, for instance, they may be checked by contact with an obstacle. The cell is sensitive to foreign bodies.

Protoplasm is sensitive.

(9) They are constantly producing fresh individuals.

Protoplasm is reproductive.

CHAPTER IV.

SPIROGYRA. *SPIROGYRA LONGATA*.

Habitat.

Spirogyra is a plant which, though still very simple; is a step above Protococcus. It is found growing in clear water, and is generally of a bright green colour, appearing as a tangled mass of bright green threads. Under the microscope these threads are seen to consist of threads all exactly alike.

Morphology.

The cells are oblong in shape, and each is surrounded by a cell-wall. The protoplasm does not fill the whole interior, but only forms a rather thick lining to the cell-wall, leaving a considerable vacuole in the interior, which, like that of Yeast, is filled by cell-sap, a watery fluid containing in solution food material, waste products, etc. Besides the protoplasmic lining there is always a spindle-shaped mass of protoplasm in the middle of the vacuole, united to the lining by thin bridles of protoplasm, and surrounding the nucleus, which is here seen very distinctly, without any special treatment, on focusing down to it. It may be described as a dense knot of a substance allied to protoplasm, though staining even more deeply with staining fluids. As it is invariably found in all cells, it must have some important function, but it is uncertain exactly what this is. It has been thought that the nucleus is concerned in cell division. The green colouring matter is not spread over the whole protoplasm, as it is in Protococcus, but is confined to the spiral band which surrounds the cells and

gives the name to the plant, and in this granules of starch are generally to be seen.

The threads lengthen continually by the division of existing cells, a process which takes place only by night. Thus any number of similar cells may be formed. Each cell is exactly like all the rest, and carries on its life independently, so that the fact of *Spirogyra* being a multicellular plant depends only on the detail that the cells, after division, do not become detached.

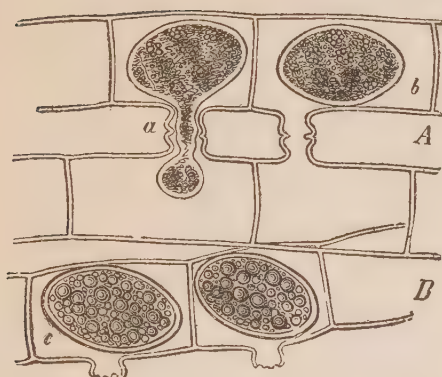
Reproduction.

When we come to the mode of reproduction, however, we find a more real advance on *Protococcus*. *Protococcus* being unicellular, the mere division of a cell into two parts produces two new individuals. In multicellular plants such a division only causes vegetative increase in the number of cells. To produce a fresh individual a special process is necessary.

The first stage in the reproduction of *Spirogyra* is that two filaments become parallel to one another. Then buds grow from each of two opposite cells and meet, and at the same time the protoplasm of the cells contracts away from the cell-wall, into a rounded mass in the middle of each cell. The partition wall between the buds is absorbed, leaving a free passage between the two cells. Usually the protoplasm in one cell begins to contract a little before that in the other, and it is the mass formed first which now passes completely over and fuses with the other, forming one mass, denser, but very little larger than either of the two out of which it was formed. The resulting mass is called a resting- or zygo-spore (*zygon*=a yoke). It soon surrounds itself with a thick cell-wall, and its protoplasm becomes loaded with drops of oil, etc. In this condition it remains at rest for some months. Then it begins to divide, and quickly produces a new *Spirogyra* filament (Fig. 86).

Here we have something quite unknown in *Protococcus*, viz., a special process of reproduction requiring special organs, which is called a process of sexual reproduction.

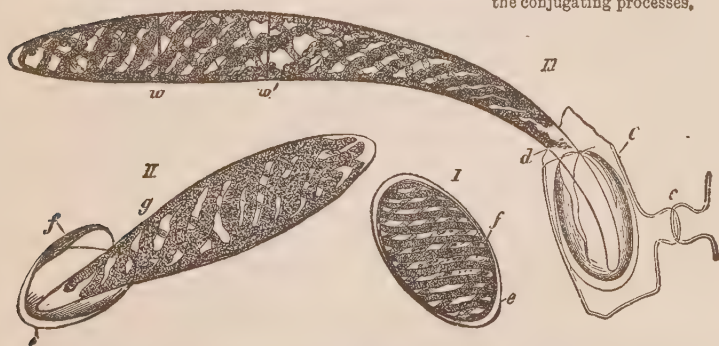
FIG. 86.



A.—The process of conjugation is almost complete. At *a* the protoplasm from the lower cell is just passing over; at *b* the process is complete.
B.—Shows two Zygospores.



C.—Two filaments beginning to conjugate; *a* and *b* are the conjugating processes,



I., II., III. are successive stages in the germination of a Zygospore. *C.* shows remains of process and cell-wall of old filament; *d.* the filament emerging; *e* and *f.* the walls of the Zygospore; *g.* the young filament dividing into cells at *w, w'*

The process is still, however, very simple. It must be noticed that the only difference between the two cells which unite is that one contracts rather sooner than the other, and passes over to join the other, which remains stationary. This process of reproduction by the union of two cells which are alike is called Conjugation.

Physiology.

Spirogyra is a green plant like *Protococcus*, and obtains its food in the same way from the water in which it grows. Like *Protococcus* also it derives the energy necessary to build up its substance out of the very simple compounds supplied to it from sunlight, in which alone it can grow. That chlorophyll is closely connected with this building-up process is shown by the fact that starch, a substance allied to cellulose, collects in considerable quantities in the chlorophyll band and corpuscles, and not in the colourless part of the protoplasm. Physiologically the cells of *Spirogyra* live in precisely the same way as those of *Protococcus*, unaffected by the detail of their connection.

PRACTICAL WORK.

Notice the matted mass of thread-like filaments, bright green to orange in colour.

Spread out and separate a few filaments, and examine first under low, then under high power. To observe the cell-wall, protoplasmic lining, and chlorophyll band, focus for the upper side of the cell. On focusing for the middle of the cell, the star-shaped internal protoplasm with the spindle-shaped nucleus comes into view.

Stain with iodine. The protoplasm and nucleus are coloured yellow, especially the latter, while the starch masses in the chlorophyll band become dark blue.

Cell-division takes place naturally during the night, but the process may be retarded and observed in the morning by placing *Spirogyra* filaments on a block of ice during the night.

Conjugation can often be observed, especially late in the season. Since the cells which pass over all belong to the same filament, one often finds at the conclusion of the process two filaments side by side, one of which contains a row of large zygospores, while the other is comparatively insignificant, being only the shrunken skeleton of empty cells.

CHAPTER V.

MOULD, *MUCOR MUCEDO*.

Habitat.

Mucor Mucedo is an example of a plant without chlorophyll which is about in the same stage of advancement as *Spirogyra*. It is a Mould, sometimes found on jam, but more often on decaying animal matter, such as stable refuse, and has the appearance of white, cottony filaments.

Morphology.

Mucor begins life as a single cell, consisting of colourless protoplasm covered by a cell-wall, and enclosing a vacuole, in all respects similar to a Yeast cell. It buds also, like a Yeast cell, but the budding is not followed by a constriction. On the contrary, the bud grows out into a long tube, called a hypha, consisting of a cell-wall, lined by protoplasm, which encloses a vacuole. This hypha branches again and again till a network of hyphae, called a mycelium, is formed. *Mucor* remains for a long time unicellular, though in other Moulds the hyphae become divided by transverse partitions. After a little while the hyphae begin to penetrate the substance on which the Fungus is growing, called the host, and about the same time branches, called aerial hyphae, are given off into the air. These swell out at the end into round heads, sporangia, which become divided from the rest of the organism by a cell-wall. The division wall curves up into the head, forming what is called the columella.

Reproduction.

The protoplasm inside the sporangium divides into a number of little round masses, which presently surround themselves each with a cell-wall. Meanwhile the wall of

the sporangium has been growing thin and brittle, with a rough, spiny outside, and at last bursts, setting free the contained bodies. They are called spores, and are exactly similar to the cells with which we began. They are very light, and can stand a great deal of drying, so they are easily wafted about in the air, until, falling on a suitable medium, they begin the story over again.

A single cell set free for purposes of reproduction is called a spore; the series of changes gone through by a plant from the time when it consists of a spore till it again reaches the same stage is called a cycle of life-history.

If, however, *Mucor* is growing on a dry substance, and has difficulty in obtaining food, it resorts to a process of conjugation essentially the same as that in *Spirogyra*. Two hyphae, formed probably from different original spores, meet and their ends come into contact. From the end of each a cell is cut off. The partition wall is then absorbed, and the two masses of protoplasm unite into one. This quickly surrounds itself by a double cell-wall, and forms a resting- or zygo-spore, which, after a period of rest, germinates and puts out a hypha. This gives off an aerial hypha, terminating in a sporangium containing spores, and thus the life-history is again complete (Fig. 87).

Physiology.

Mucor, like Yeast, must be supplied with ready-made food material, and this it obtains from the host on which it grows. Since it absorbs its food from dead or decaying matter it is called a Saprophyte (*sapros*=rotten, *phuton*=a plant). Fungi which prey upon a living host are called parasites.

If *Mucor* be submerged in a liquid, and kept from air, it passes into what is called its yeast-like or toruloid condition. Its buds separate like those of Yeast, and it becomes capable of setting up fermentation. On again obtaining access to air, it resumes its normal mode of growth.

Classification.

Spirogyra and *Mucor* present no distinction into stem and leaves, and are therefore Thallophytes like *Protococcus* and

Yeast. They differ, however, from these, in that while Yeast and Protococcus have no special process of reproduction other than mere cell-division, Spirogyra and Mucor reproduce

FIG. 87.



- A.—Section of a Sporangium, showing columella and spores.
 B.—Semi-diagrammatic view of *m*, mycelium; *g*, sporangia of *Mucor* slightly magnified.
 C.—A zygospore, *z*, to which the conjugating hyphae are still attached, with the hyphae, *h*, and sporangium, *g*, which it bears.
 D.—Conjugation; *b*, hyphae; *a*, conjugating cells.

themselves by the process of conjugation. Protococcus and Yeast are therefore classified as Protophytes, while Mucor and Spirogyra belong to the higher class of the Conjugatae.

PRACTICAL WORK.

Mucor may easily be cultivated by sowing spores on a piece of bread soaked in water; or if bread be kept moist and warm under a bell-jar Moulds will spontaneously appear, and it is probable that after four or five days the long white threads of Mucor will be observed. The heads of these, easily visible to the naked eye, are white at first, but turn black after a time.

Strip off some, mount in alcohol, and examine under low and high power. Mount a few on a dry slide, add water, and watch the effect.

When the Mould has been growing for some time, tease out a little of the bread in water, and study the structure of the nonseptate branched hyphae.

The toruloid condition may be obtained by cultivating Mucor immersed in a nutritive solution, as, for instance, Pasteur's Solution.

The zygospores when present appear to the naked eye as black bodies projecting from the substratum. They are very often not to be found at all. They are most frequent on horse-dung cultures. If present, they should be removed very carefully to a slide, so as, if possible, not to tear the remains of the conjugating hyphae. If, however, these are torn, their ends can be recognised as circular spots on the zygospore. In fortunate cases, previous stages in the process of conjugation may be met with by examining parts of the old mycelium.

CHAPTER VI.

VAUCHERIA. VAUCHERIA SÈSSILIS.

Habitat.

Vaucheria Sessilis is a filamentous green Alga found growing in water, and also on damp earth, *e.g.* in conservatories. The filaments are large enough to be distinguished by the naked eye, and in a well grown patch are thickly interwoven.

Morphology.

These filaments are found under the microscope to be long cylindrical tubes, rounded at the ends, and branching but seldom. In a healthy state the filaments are not divided by transverse partitions except in connection with reproduction. Certain branches (rhizoids) are modified as organs of attachment. They are colourless, and ramify in the soil. The main branches consist of a cell-wall, lined by protoplasm, which encloses a large vacuole, and they sometimes grow to a length of as much as twelve inches. The green colour is not distributed uniformly as in *Protococcus*, but is confined to special rounded masses of the protoplasm, known as chlorophyll granules or corpuscles. The protoplasm is also full of drops of oil, and contains numerous small nuclei, which can be brought into view by a process of staining.

Reproduction.

So far, the account of *Vaucheria* differs only in details from that given above of *Spirogyra*; but when we come to consider reproduction, we find a different and a more complicated state of things. In *Vaucheria*, as in *Spirogyra*, special branches

arise, by the union of whose contents new plants are formed; but in *Vaucheria* these branches, instead of remaining simple and alike, are modified into organs of two kinds, known as *Antheridia* and *Oogonia*.

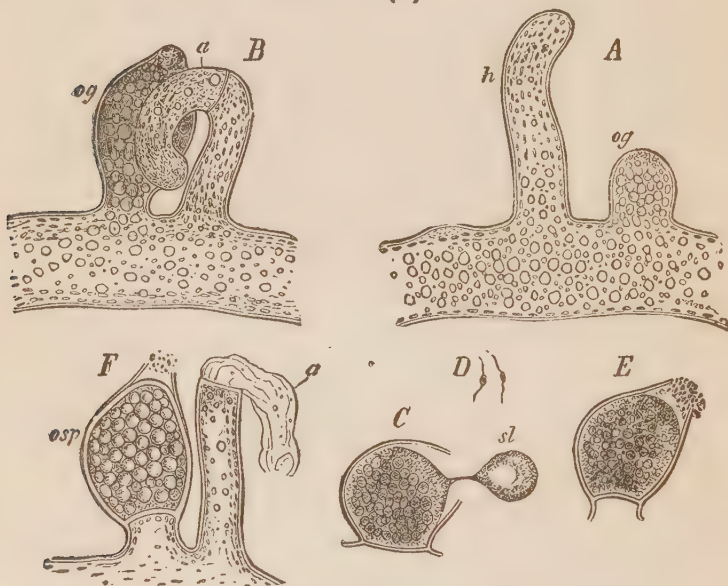
The antheridium consists of two parts. The lower half is exactly like an ordinary branch, and is straight, but the upper half is cut off from the lower by a transverse partition, and is curved round. As it matures it loses its green colour, and finally its protoplasm divides into a great many small masses known as antheridzoids. The tip of the antheridium is ruptured, and the antheridzoids escape. They put out each two cilia, by means of which they are able to move.

The oogonia are also modified branches. Each consists of an obliquely ovoid cell, cut off from the filament which bears it by a cell-wall, and they retain their green colour. In *Vaucheria Sessilis* two oogonia generally arise near together, with an antheridium between them. When mature, the oogonium forms an oblique process at the side towards the antheridium. The apex of the process opens, and a small portion of clear protoplasm is exuded, while the remaining green protoplasm contracts away from the cell-wall, and is called the oosphere. The antheridzoids then enter, and coalesce with the oosphere. This process of union of cells which are not alike is called fertilisation. After fertilisation the oosphere is changed into the oospore, which speedily forms a thick cell-wall, and becomes red or brown in colour. After a period of rest it germinates and produces a new plant. Fertilisation resembles conjugation in that it consists in the union of two separate masses of protoplasm, but it differs from conjugation in that the masses which unite are unlike before their union (Fig. 88).

Vaucheria has also another mode of reproduction which does not depend on any kind of union of cells, but which takes place in the following manner. The end of an ordinary branch is cut off by a septum, and the protoplasm of this terminal cell contracts away from the cell-wall, and forms an oval mass in the interior of the cell. The end of the cell

opens, and the protoplasmic mass escapes, rotating as it goes by means of the cilia with which it is covered. It is known as a swarm spore or zoogonidium. If the opening is very small, sometimes only half the cell escapes, and the other half is left rotating within the mother cell. After a few hours the swarm cells secrete a cell-wall, settle down, and germinate and produce new plants.

FIG. 88 (I).



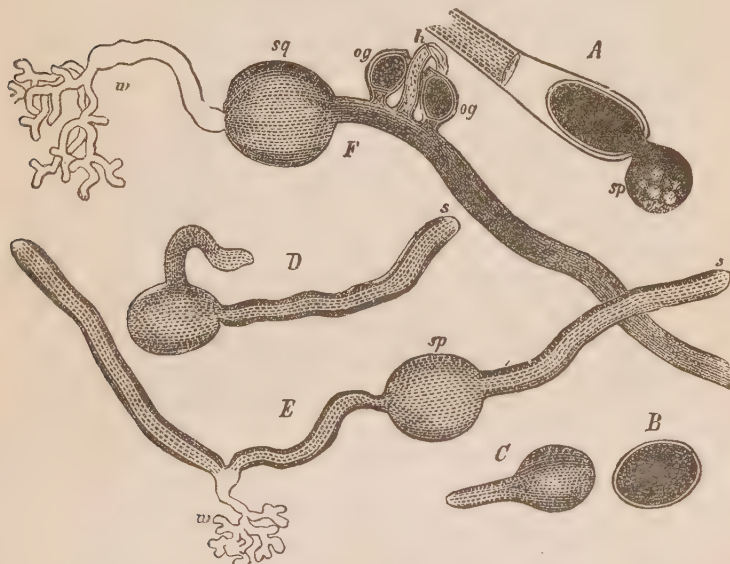
- A.—Antheridium, *h*, and oogonium, *og*, arising from a filament as branches.
 B.—The same further developed. The true antheridium, *a*, separated from the stalk.
 C.—An oogonium opening and exuding the clear drop, *sl*.
 D.—Antheridzoids.
 E.—Antheridzoids entering oogonium, in which oosphere is formed after fertilisation.
 F.—The antheridium, *a*, is empty, and the oogonium contains the oospore, *osp*.

Occasionally *Vaucheria* may be found in a peculiar resting condition, the filaments divided into separate cells by thick glutinous partitions. The separate cells are capable of developing more or less directly into new plants.

Physiology.

Vaucheria is a green plant, and is capable of manufacturing itself out of the same simple food as *Spirogyra*, and it is, like *Spirogyra*, dependent on sunlight for the exercise of this power. It must be noted that the formation of antheridia

FIG. 88 (II.).



A.—The end of a filament from which a zoospore, *sp*, is just escaping.

B.—The zoospore after coming to rest.

C, D, E, F.—Stages in the development of the *Vaucheria* plant; *w*, rhizoid; *og*, oogonium; *h*, antheridium.

and oogonia goes on during the night, beginning in the evening, and being complete in the following morning. Fertilisation ensues during the next few hours. The swarm cells also are formed during the night, and escape in the morning.

PRACTICAL WORK.

Obtain some of the green Felt to be found on pots in conservatories : select rather a large, old patch, and carefully tease it out in a drop of water.

Examine the filaments, and make out the structure described above, first under low and then under high power. The protoplasm and cell-wall can be distinguished more readily after treatment with 2 per cent. salt solution. The nuclei can only be seen after careful staining.

Examine the antheridia and oogonia in detail. Watch for the escape of the antheridzoids. To observe these and their cilia, treat with iodine.

If possible, examine a series of specimens showing the development of antheridia and oogonia from their origin as simple branches till the process of fertilisation is complete. Since this takes place at night it must be studied in the daytime by means of a series of prepared specimens.

Look out for older examples to see the changes which take place in the oospore after fertilisation.

To find swarm spores, place a mass of *Vaucheria* in water and expose it to light. Early next morning, after the night's darkness, examine it. (If this is inconvenient, put it in a cupboard for the night, and keep it in the dark till it is wanted.) Some of the filaments will be seen with a lens to have swollen, rather dark-coloured ends. Mount these very carefully, and observe as above.

Note that the protonema of a Moss, or perhaps other filamentous Algae, may be found instead of *Vaucheria*. They can be recognised by their filaments being partitioned off into separate cells. The genus *Vaucheria* itself has many species, distinguished chiefly by the number and form of the reproductive organs. In *Vaucheria Sessilis* the antheridia and oogonia are inserted separately on the main filament, as described above. *Vaucheria Terrestris* may very likely be found instead of *Vaucheria Sessilis*, and here the antheridium and oogonium arise together on a common stalk.

CHAPTER VII.

PYTHIUM. PYTHIUM DE BARYANUM.

Habitat.

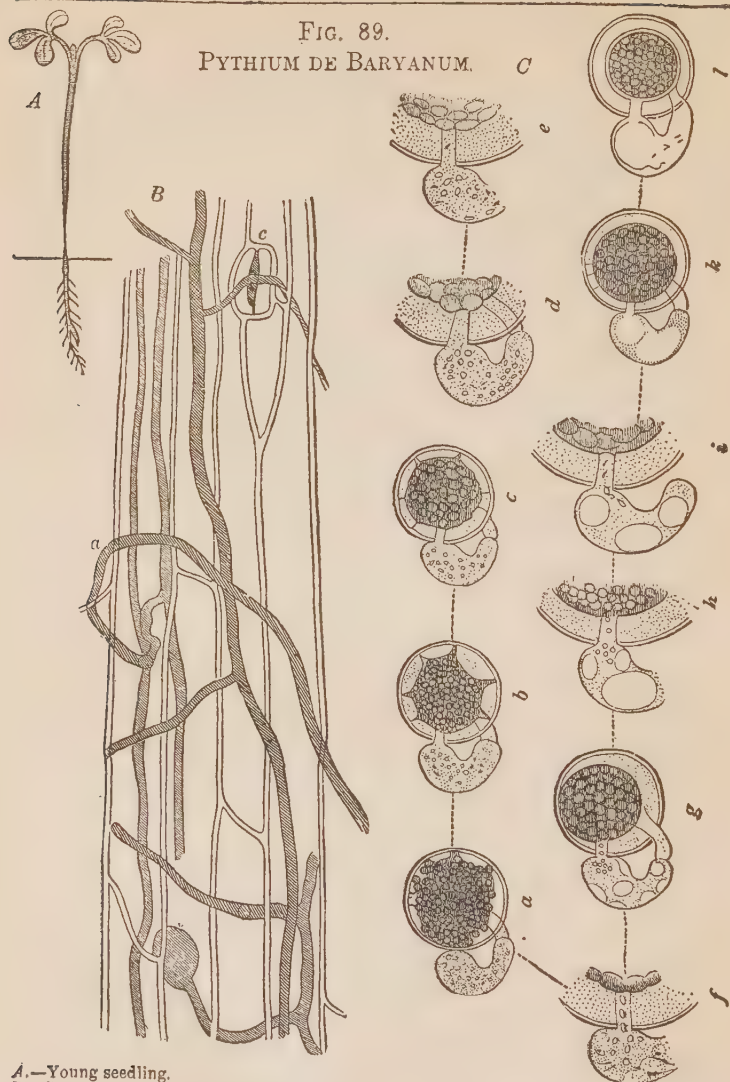
Pythium de Baryanum is a Fungus, parasitic on seedlings, and especially on the seedlings of Cress.

Morphology.

Pythium, like Mucor, consists of a number of branched hyphae, not divided into separate cells. These consist of a cell-wall, lined by protoplasm, enclosing a vacuole, with numerous small nuclei, but no chlorophyll corpuscles. They apply themselves at first to the surface of the plant on which they live, but soon the branches begin to enter the tissues of the host, sometimes through the opening of a stoma, but more often by piercing the epidermis. They then ramify within its substance, forming a mycelium, similar to that of Mucor. (Fig. 89 B.)

Reproduction.

When young, Pythium reproduces itself by means of simple cells separated off from the hyphae. Swellings are formed either at the ends of the hyphae or at certain points along their course, and these are separated by cell-walls, and filled with granular protoplasm, while the hyphae in their neighbourhood are emptied. The outer wall becomes dark-coloured, and after a time these cells, known as brood cells, spores, or gonidia, are set free. They are capable of resisting drought and change of temperature, and on reaching water they germinate, send out fresh hyphae, and so complete the life-history. It is stated that in some cases the gonidia, before germinating, divide into a number of swarm cells, and that these by-and-by settle down and germinate.



A.—Young seedling.

B.—Surface view of epidermis of the above (magnified): a, mycelium; b, spore; c, stoma, through which a hypha penetrates.

C.—a, b, c, d, e, f, g, h, i, k, l, successive stages in the process of fertilisation (highly magnified).

Reproduction by means of special organs, the antheridia and oogonia, takes place in *Pythium* at a later period. The oogonium arises as the swollen globular end of a hypha, very much like a gonidium. It is cut off by a cell-wall, and the protoplasm contracts to form a granular mass, the oosphere. The antheridium arises usually as a branch of the same filament which forms the oogonium. The end of the antheridial branch is cut off by a cell-wall, and applies itself closely to the oogonium.

From the antheridium a process, called the fertilisation tube, grows out, and penetrates the oogonium till it reaches the oosphere. (See Fig. 89 C.) Antheridzoids are not formed, but the contents of the whole antheridium pass over and coalesce with the oosphere. As a result the oosphere, now become the oospore, surrounds itself with a cell-wall, and undergoes a period of rest, still enclosed in the oogonium. Finally it germinates, sending out hyphae, etc. Sometimes the contents of more than one antheridium coalesce with a single oosphere.

Physiology.

Pythium, like *Mucor*, is destitute of chlorophyll, and consequently must be supplied with ready-made food. This it obtains from the cells of its host, and it is therefore called a parasite. Its growth is quite independent of light.

Classification.

Vaucheria and *Pythium* have been selected as examples, one from the Algae, the other from the Fungi, of plants which, though otherwise little advanced beyond *Spirogyra* and *Mucor*, exhibit a higher form of the reproductive process. The cells which unite are unlike one another, and are produced in special organs unlike one another. The process is called fertilisation, and, since its result is the formation of an oospore, these plants are said to belong to the class Oosporeae.

PRACTICAL WORK.

To obtain Pythium, sow seeds of Cress in a pot; cover it, and keep it very moist and warm. The seedlings will grow rapidly, and then become diseased. The stem will be found pale and flabby at a certain point, and will bend sharply over. The disease, which attacks many forced plants, and which is known by gardeners as "damping off," is due to the attacks of Pythium. Delicate hyphae may be seen at the point of curvature, and after a few days will increase to form quite a mass of white threads, while the seedlings rot away.

Examine the diseased seedlings under a low power. Afterwards tease out a part of the diseased tissue, and observe the character of the mycelium, and the way in which it attacks the tissues, as described above.

Cut sections of similar specimens which have been hardened in alcohol, and repeat the examination.

To obtain gonidia, place the diseased seedlings in a little water, and examine them from day to day, till gonidia appear. When numerous gonidia have appeared, take a little of the Fungus, and place it in a watch-glass full of water. After a day or two the gonidia will be found germinating.

Continue the observations after the appearance of gonidia till oogonia and antheridia are formed. The actual process of fertilisation may be observed in this plant if a small portion of the fungus, which has already formed numerous gonidia, be continuously observed as follows:—

Cut a piece of thick porous cardboard to the size of a slide. Punch out a hole of such a size as to be covered by a coverslip. Boil the cardboard in the water so as at the same time to kill all germs and to saturate it. Place a small portion of the Fungus in a drop of decoction of French plums on a coverslip, and invert this over the hole in the cardboard. The Fungus can then grow in the drop, evaporation being prevented by the moist cardboard surrounding it, and can be continually inspected. The cardboard must, of course, be moistened from time to time.

CHAPTER VIII.

SEA-WEED. BLADDER-WRACK. *FUCUS VESICULOSUS*.

Habitat.

We are all familiar with the ordinary brown Sea-weed or Bladder-Wrack, whose air-bladders give it the name *Fucus Vesiculosus*.

Morphology.

Fucus consists of a number of cells, many thousands going to form one frond, and these cells are not all alike. The study of various kinds of cells forms the subject of histology (*histos*=a web). The fronds are bilobed at the end, and have a thickening, forming a kind of midrib down the middle, which forks so as to extend into the lobes. The older parts are round and thick, resembling a stem, and the base is modified into an organ of attachment, so that *Fucus* is morphologically more advanced than any of the preceding plants. Similarly an examination of a thin section under the microscope shows a distinction into closely packed cells forming the cortical tissue, and a loose, irregular medulla or pith. The histological differentiation is accompanied by a physiological differentiation; division of labour begins to arise, different cells having different functions to perform.

Detailed examination of the thallus reveals the following structure. Externally the cortex consists of one tolerably distinct epidermoid layer composed of rectangular cells, within which are several rows of less regular, larger cells. The extra thickening of the midrib is due to growth and division of these cells of the under part of the cortex. The medulla, on the other hand, which is found in

the interior of both midrib and wings, is composed of cells arranged in rows, which are separated from one another by an intercellular jelly, formed by a swelling up of the outer layers of the walls of the cells, which thus appear imbedded in a mass of jelly. These filaments communicate occasionally by transverse threads, thus forming a kind of network. In the older parts the wings fall away, leaving only the thickened midrib. A careful examination shows that the cell-walls of both cortex and medulla are perforated by pits, through which the protoplasm is said to be continuous from cell to cell. The cells contain corpuscles bearing chlorophyll, and in addition another colouring matter, the two together giving the olive-brown colour of the plant.

By means of a simple lens, irregularly scattered dots may be observed over the whole thallus, with the exception of the mid-rib. In sections these appear as flask-shaped hollows, lined by hairs which project from the small openings. It is possible that these hairs serve to absorb water and food.

The young bladders are seen in section to be filled by threads similar to these of the medulla. Later on these threads are separated, and the spaces between become filled by air.

In *Fucus*, though growth is not confined to the apex, there is yet a distinct growing point situated in the hollow at the end of each frond. The branching characteristic of *fucus* is due to the forking of this growing point, and is called dichotomy. Notice that of the two branches formed at each fork; one always develops more strongly than the other.

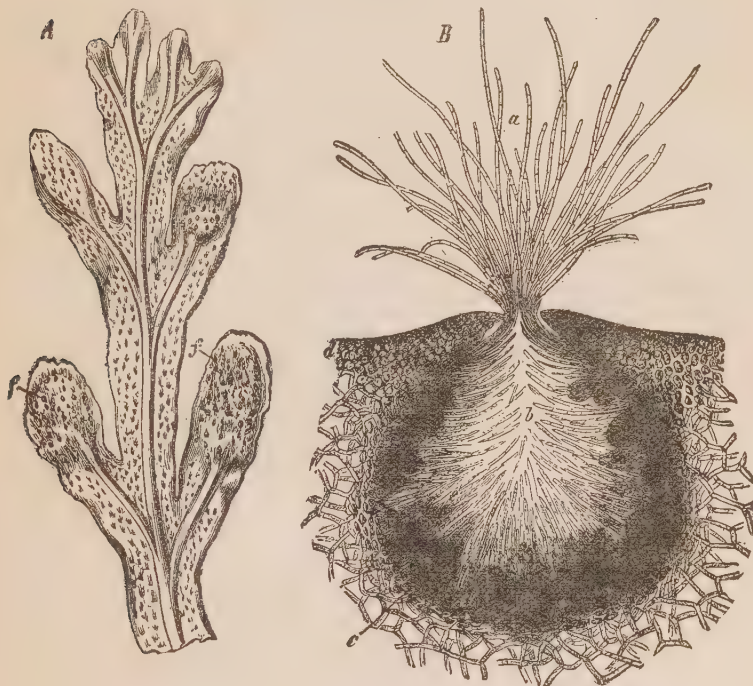
At the base of the thallus the tissue divides into filaments which grow out and apply themselves very closely to stones, rocks, etc., and thus form an organ of attachment. Branches may also be developed from the base of the thallus.

Reproduction.

To the naked eye some branches appear to be swollen and marked all over by pin-pricks. These are the fertile fronds. If sections be cut, the pin-pricks will be found to be the openings

of flask-shaped hollows similar to those described above, and called conceptacles. The fertile conceptacles are also lined by projecting hairs, but amongst these the organs of reproduction are to be found—the antheridia in some conceptacles and the oogonia in others.

FIG. 90.



A.—Sketch of a part of the thallus of *Fucus*; *f*, the opening of a conceptacle.

B.—Section, much magnified, of a fertile conceptacle of *Fucus Platycarpus*; *a*, hairs; *d*, cortex; *c*, medulla; *b*, internal hairs.

The antheridia are single cells, borne several together on a much-branched hair. They escape from the conceptacle, and then their protoplasm divides into numerous—it is said sixty-four—small masses, the antheridzoids. These put out

two cilia, by means of which they move through the water.

Each oogonium is really also a modified hair, and consists of two cells, the lower of which acts as a stalk to the upper, a large oval cell. The protoplasm of this last divides into eight round masses, the oospheres. It then separates from its stalk and escapes from the conceptacle. It has a double

FIG. 91.



A.—Hair bearing several antheridia, *a*,
B.—Antheridzoids.

I.—Og, Oogonium with hairs, *p*.

II.—Oogonium set free, its outer coat burst
and the eight oospheres, *t*, already

rounded off; *a*, the remains of the
outer coat.

III.—An oosphere surrounded by anther-
idzoids.

IV. and V.—Stages in the growth of a
Fucus plant.

wall, and bursts in two stages, as shown in Fig. 91, but finally the oospheres are set free. They have no cilia, so they only drift in the water till they meet the antheridzoids. A number of these surround each oosphere, and one or more coalesce with the oosphere and fertilise it. The oospore at once forms a cell-wall, and begins to divide, forming a new Fucus plant, and thus completing the cycle.

The process of fertilisation is essentially the same as in *Vaucheria* and *Pythium*, but it is here very clear and perfect. The cells which unite are both fully developed, and are set free before their union, but are extremely different—the antheridzoids small and motile, the oosphere much larger and non-motile. We shall not find any example of fertilisation in higher plants so perfect as that of *Fucus*. Notice also that this is the only mode of reproduction found in *Fucus*.

Physiology.

Fucus is an Alga. It obtains its food in a simple form from sea-water, and is able, like *Protococcus*, to build up its own substance by means of its chlorophyll, and in presence of sunlight. Its cells are entirely devoid of starch, but on the other hand are rich in oil. Notice that there is a certain amount of division of labour here, the outer cells being specially fitted for purposes of protection, the inner for absorption and various active processes.

PRACTICAL WORK.

Sea-weeds must be examined in sea-water (a solution of Tidman's sea-salt will serve), since they swell up very much in fresh water. It greatly facilitates the cutting of sections to previously treat the material with 1 per cent. chromic acid, wash with water, and harden by placing successively in 30, 50, 70, and 90 per cent. alcohol. It is possible; however, to use fresh material.

Examine the thallus, and make out the chief morphological characters. If treated with alcohol for about twelve hours the brown colouring matter is dissolved, and the thallus is then seen to be green. Later the chlorophyll is also dissolved, and the thallus appears bleached, while the spirit becomes bright green.

Prepare sections of the thallus, and observe the structure as described above. Notice the cortical layer, medulla, sterile conceptacles, apex, midrib, wings, air-bladders, etc.

The fertile branches are swollen, the antheridial ones yellowish, and the oogonial dark green in colour. It is best to prepare median longitudinal sections of these fronds, so that a series of conceptacles of successive ages can be observed.

Fresh material is necessary for the observation of the antheridzoids and oospheres. Observations are of course more easily made at the coast, and should be carried on in winter or early spring. Inland students may, however, proceed as follows:—Place fresh *Fucus* on its arrival in a solution of Tidman's sea-salt to let it recover itself after its journey. Then hang up the plants on strings, and thus expose them to the air for about six hours. The reproductive organs will be exuded, and, to the naked eye, the antheridia will form

aa orange, and the oogonia an olive-green mucilage on the surface of the fertile fronds. A little of each mucilage should be mounted in separate drops of sea-water and examined. Antheridia and oogonia, or, at a later stage, antheridzoids and oospheres, may be observed.

To a preparation where the oospheres have just been set free, add a little of the orange mucilage, and notice antheridzoids swarming round the oospheres. The actual process of fertilisation will not be observed because of the opacity of the oospheres.

CHAPTER IX.

MUSHROOM. *AGARICUS CAMPESTRIS*.

Habitat.

Agaricus Campestris is the Common Mushroom found growing on the soil (humus) of fields, etc.

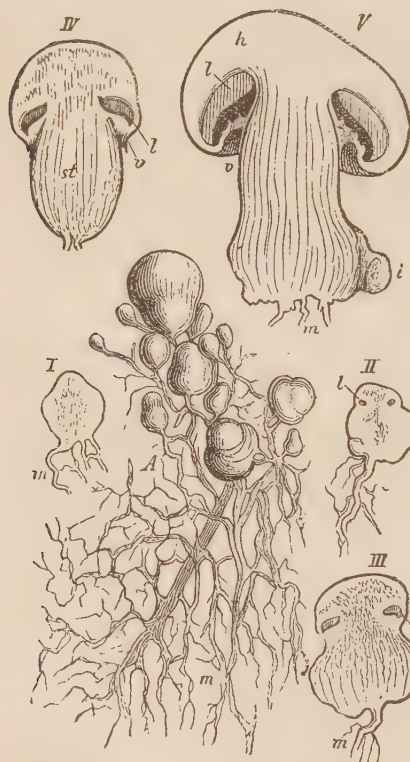


FIG. 92.

MUSHROOM.

m, the mycelium.
I. II. III. IV. V., sections at successive stages of development.

st, stipes.
v, velum parziale.
l, lamellae or gills.
h, pileus.

Morphology.

Mushroom is a Fungus consisting of hyphae, similar to

those of *Pythium*, but divided into very long cells by transverse partitions at intervals. These form a network or mycelium in the soil, from which the mushroom, popularly so called, arises.

FIG. 93.

MUSHROOM.

A.—Section of pileus; *h*, bearing several gills, *l*.

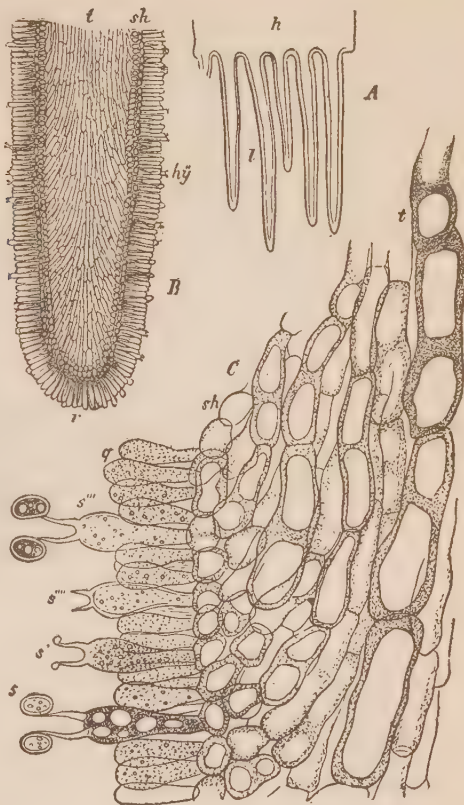
B.—Section of a gill: *t* is the spongy tissue; *sh*, the sub-hymeneal; and *hy*, the hymeneal layer.

C.—Fragments of the above more highly magnified.

q, Paraphyses.

s''', s'''', Sterigmata.

s', s'', Spores.



This is in fact the spore-bearing structure. When young it is simply a rounded upward growth, but as it grows the upper part dilates to form the pileus, supported on a cylindrical stalk, the stipe. As the pileus dilates, the tissue on its under side, called the veil, or velum partiale, is

ruptured, leaving a ring or annulus where it was attached to the stipe, and an irregular fringe round the margin of the pileus. The lower side of the pileus now consists of vertically placed, dark-coloured gills or lamellae, radiating out from the stipe, and from which a fine dark-coloured dust falls slowly, as can be seen if the mushroom be placed on a sheet of white paper for some time.

Sections of the stipe and pileus reveal the fact that these solid-looking masses of tissue are really only collections of hyphae, which run on the whole in the same direction, but which branch occasionally, and are interwoven with one another. In the interior of the stipe the hyphae are separated by spaces filled with air, while in the external part or cortex they are more closely arranged. The pileus consists of much-branched hyphae, separated from one another by air spaces, and massed to form an apparent or false tissue. The hyphae run along the length of the gills, and then curve downwards to the free surface. Their terminations, at the free edge of the gills, form the following layers:—

- (1) The sub-hymeneal layer of short, closely packed cells.
- (2) The hymeneal layer, consisting of oblong cells, some of which have simple rounded ends, and are called paraphyses, while others, the basidia, bear each two fine thread-like processes, the horns or sterigmata, at the end of each of which is a spore.

By the germination of these spores fresh individuals are produced, and thus the life-history is complete.

Very careful investigations have failed to discover any special reproductive organs or process of fertilisation in Mushroom, and it is probable that nothing of the sort exists.

Physiology.

Mushroom is destitute of chlorophyll, and absorbs its food ready made from decaying animal matter. It is therefore a Saprophyte. It requires a good deal of moisture, and flourishes best at a rather high temperature.

Classification.

Fucus and Mushroom have been taken as types of the most highly developed Thallophytes, especially with a view to comparing development in the self-supporting Algae with that in the parasitic Fungi. It is sufficiently striking that while the vegetative mass of Fucus shows considerable advances towards the complicated structure and division of labour which we find in higher plants, Mushroom consists of a mycelium practically the same as that of Pythium or Mucor. Again, while Fucus presents the process of fertilisation in a most perfect form, this is entirely wanting in Mushroom. In forms nearly allied to Pythium the reproductive organs are present, but fertilisation never takes place, so that they are useless to the plant. In Mushroom they are no longer formed.

PRACTICAL WORK.

To grow Mushrooms for laboratory use, proceed as follows :—

Buy a “brick of Mushroom spawn.” This consists of dried cow’s dung, loam and clay, penetrated by the mycelium of the fungus. Break the brick into pieces, and bury them in a mixture similar to that of the brick. Keep the culture warm and moist in the dark for about a week, till Mushrooms appear.

Take a small portion of the mycelium, tease it out in water, and make out the structure of the hyphae.

By carefully clearing the mycelium, its connection with the Mushrooms can be made out.

Compare the appearance of Mushrooms of different ages.

Observe in a mature Mushroom the stipe, pileus, gills, velum partiale, etc., as above described.

As with *Fucus*, sections may be made from fresh material, but will be more easily and successfully cut from material treated as there described.

Cut transverse and longitudinal sections of the stipe, and tangential sections of the pileus and gills, to observe the layers described above.

Remove a single gill from a fresh Mushroom, and observe with the low power the basidia, paraphyses, and the way in which the spores arise, two from each basidium.

CHAPTER X.

CORD MOSS. *FUNARIA HYGROMETRICA*.

Habitat.

Funaria Hygrometrica is a very common Moss on old walls, well shaded cinder-paths, etc.

Morphology.

It consists of a small, much-branched stem, bearing leaves. Like all other Mosses it has no roots, but the purposes of a root are fulfilled by root-hairs.

The stem shows differentiation into :—

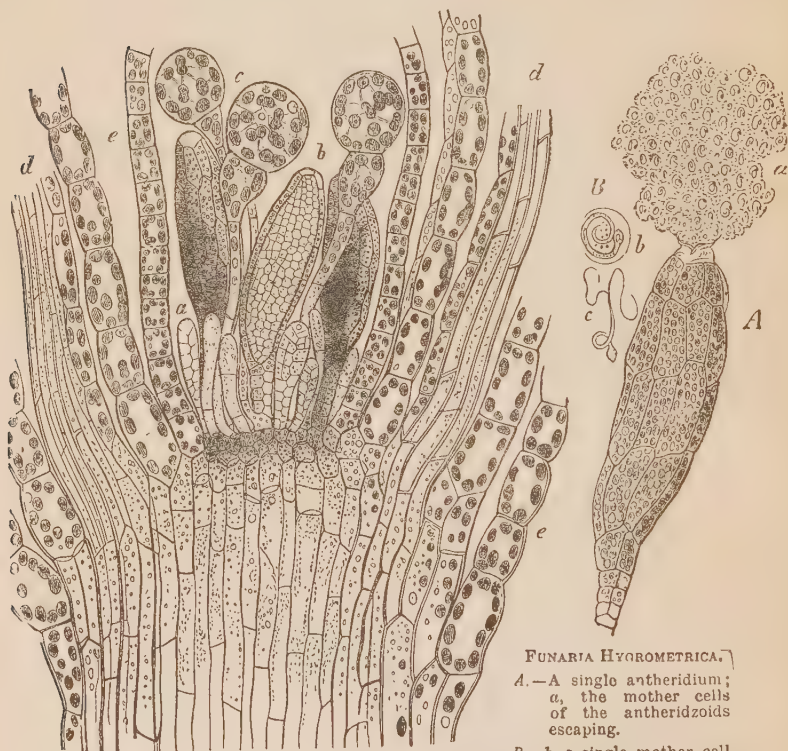
- (1) Several rows of closely packed cells, whose walls are hardened, dark-coloured, and very much thickened, so that the enclosed cavities are only quite small.
- (2) An internal tissue, whose cells are thinner walled, more loosely packed, and with more abundant cell contents.
- (3) A central group of long, very thin-walled cells.

This histological differentiation again suggests division of labour. The external cells are thick-walled to serve as an external protection. Their cell contents are sacrificed so that they may be mechanically stronger, and consequently the active processes must be performed almost entirely by the internal cells. We see, then, that in its morphology, its histology, and its physiology, *Funaria* is more advanced than *Fucus*. The use of the elongated cells of the middle will appear from a comparison with similar tissues in higher plants. The leaves are but one layer thick, except along their midrib. The stem ends in a large dome-shaped cell, from

the three-sided pyramidal base of which successive segments are cut off, which by their divisions give rise to the leaves, and to the tissues of the stem. The young leaves are crowded behind the apical cell so as to form a bud. From the lower part of the stem root-hairs are given off into the soil.

C

FIG. 94 (I.)



C.—The end of the stem with the bases, *d* and *e*, of leaves; *c*, paraphyses; *b*, antheridia.

FUNARIA HYGROMETRICA.

A.—A single antheridium; *a*, the mother cells of the antheridoids escaping.

B.—*b*, a single mother cell still more magnified; *c*, a free antheridoid.

Reproduction.

The reproductive organs of Moss are of two kinds, antheridia and archegonia (archegonia=oogonia), but many

Mosses, *e.g.* *Sphagnum*, the Bog Moss, very rarely produce them, depending as a rule on vegetative growth. For instance, in *Sphagnum*, the end of the stem goes on growing, while the older parts die off behind, so that what were originally branches come to be separate individuals. Also gemmae or buds are often separated and grow into new plants.

The antheridia and archegonia are found in *Funaria*, as in most true Mosses, at the apex of the stem, within the bud formed by the young leaves; and in *Funaria* one stem bears the antheridia and another the archegonia. These organs are found mixed with sterile hairs, called paraphyses.

An antheridium is a shortly stalked bag of cells, which when ripe opens up at the top, and sets free the contained cells. Then from each of these cells the protoplasm escapes, forming an antheridzoid, which has two cilia.

An archegonium is a flask-shaped body, consisting of a central row of cells, covered by an external layer. The lowest and largest of the cells of the central row is the oosphere. The rest after a time become converted into mucilage, and so leave the interior of the neck free for the entrance of the antheridzoids, which swim down and coalesce with the oosphere, forming an oospore.

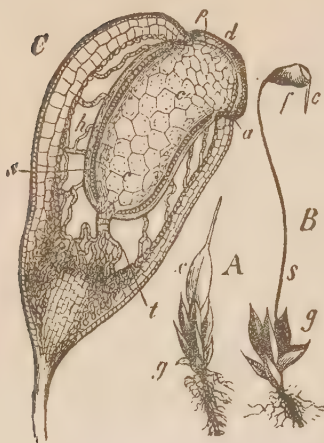
FIG. 94 (II.)



- A.—End of stem with archegonia, *a*, in position; surrounded by bases of leaves, *b*.
 B.—An archegonium more strongly magnified; *m*, neck; *h*, canal cells; *b*, oosphere.
 C.—The neck of an archegonium still more magnified.

In *Funaria*, however, the cycle of life-history is not yet complete. The development

FIG. 95.



A.—Plant of *Funaria*, with young sporogonium attached; *c*, the calyptra.

B.—The same with mature sporogonium; *s*, seta; *f*, sporogonium; *c*, calyptra.

C.—Magnified section of a sporogonium; *a*, annulus; *s*, spores; *d*, operculum; *c*, columella; *p*, peristome; *h*, tissue of sporogonium.

of the oospore does not lead at once to the formation of a new Moss plant, but to that of an intermediate structure, popularly known as the "Moss fruit," more correctly as the sporogonium.

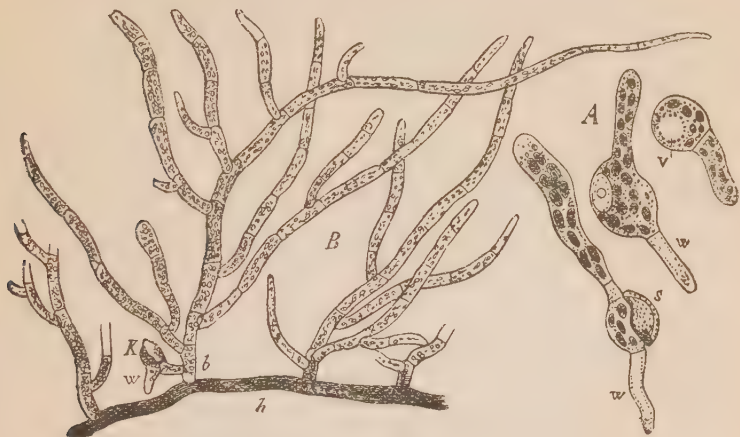
The oospore divides horizontally into two halves. The lower divides repeatedly by transverse partitions only, and thus forms a long stalk, the seta. The upper half forms, in course of time, an oval body, the sporogonium. This consists, when mature, of a central mass of cells, the columella; of a covering membrane; and, between these, of a number of spores. The apex of the sporogonium is modified into a circular lid,

the operculum, edged by a row of cells, the annulus. In the development of the sporogonium from the oospore, the archegonium is torn, and the upper part, carried up by the growing sporogonium, comes to form a little pointed cap, the calyptra. Under the operculum is a layer of cells, the peristome, with curiously thickened woody walls. When this tissue swells on taking up water the sporogonium opens, and sets free the contained spores. Falling on damp earth, these germinate. They form at first a number of green filaments called the protonema, and the new Moss plant arises as a branch of this.

It must be specially noticed that the life-history of Moss presents no longer a simple cycle, as in the plants studied

hitherto, but that there distinctly is a double cycle. What we ordinarily call the Moss plant bears reproductive organs, and produces as its final result an oospore. It is therefore called the oophore, or egg-bearing, generation or cycle. But the

FIG. 96.



A.—Stages in the germination of a spore of Moss; *v*, vacuole; *w*, root-hair.
B.—Protonema of *Funaria*; *K*, young Moss plant with root-hair, *w*.

oospore is the starting-point for a fresh cycle, which includes the sporogonium, and which leads as its result to the formation of spores. This is accordingly called the sporophore generation. The spores on germinating produce a new oophore generation, and so on, in strict alternation. Thus the life-history of Moss may be represented by the following diagram.

FIG. 97.

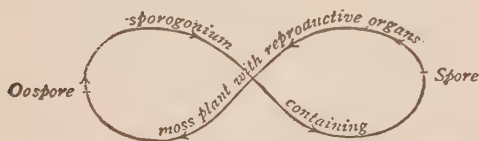


Diagram of life-history of Moss, illustrating alternation of generations.

It is the strict alternation of the two cycles which is the special distinction of the Mosses from any plant

hitherto considered. It is true that in *Mucor*, in *Vaucheria*, and in *Pythium* there were two cycles, the formation of new plants depending in the one on spores, and in the other on oospores, but in those plants the two modes of reproduction were quite distinct, with no sign of interdependence. In Moss, however, the two cycles, while even more distinct from one another than before, can only arise each from the other, and we have, for the first time, *alternation of generations*.

Physiology.

The cells both of stem and leaves are rich in chlorophyll, and the mode of life is essentially the same as that of *Vaucheria*. Like all green plants, the Mosses are dependent on sunlight.

Classification.

Funaria belongs to the second group of the Vegetable Kingdom, the Muscineae, of which the distinguishing characteristics are :—

- (1) The plants have stem and leaves, but no true roots.
- (2) They present distinct alternation of generations.

The first point distinguishes this group from those above it, the second from those below.

PRACTICAL WORK.

Examine specimens of *Funaria*, and verify the facts mentioned above.

Cut sections of the stem, and observe the different kinds of cells.

Mount a leaf, and observe the single layer of cells, very rich in chlorophyll corpuscles.

To see the antheridia and archegonia, which in *Funaria* are produced all the year round, the terminal buds must be carefully dissected. Under the simple microscope this can be done much more easily. The stems bearing antheridia are somewhat shorter than those bearing archegonia.

In older specimens, examine the sporogonia.

Harden some of these in alcohol, imbed in paraffin, and cut sections, to make out the structure.

Cultures of protonema may be obtained by inverting fine sods of *Funaria*, and growing them for two or three weeks in moist air under a bell-jar.

CHAPTER XI.

FERNS. *ASPIDIUM FILIX-MAS. PTERIS AQUILINA, Etc.*

WE now pass to the third group of the Vegetable Kingdom, the Pteridophyta—of which *Aspidium Filix-mas*, the Male Shield Fern, and *Pteris Aquilina*, the Bracken Fern, are examples.

Morphology.

Fern is a step above Moss morphologically, for it possesses a true root, as well as stem and leaves. The stem is generally underground, and is called a rhizome. In the Harefoot Fern it creeps along just at the surface, so that the blunt, rounded apex and numerous branches are visible. In Bracken the rhizome is at a considerable depth in the soil, frequently branches, and gives off leaves or fronds from one side, and roots from the other. In *Aspidium* the rhizome ascends, and is quite covered by the bases of old leaves. It does not branch behind the apex, but branches and roots are given off from the bases of the leaves. A number of young leaves, each curled up like the head of a crozier (circinnate vernation) are to be found near the apex, covered and mixed with numerous brown scales. The apex is blunt. The roots are thin, dark, wiry, and branched.

Histology.

On examining under the microscope thin sections of the rhizome of a fern, we find a histological advance in addition

to the above-mentioned morphological advance, for the stem consists of three distinct tissues ; in addition to the epidermis

FIG. 98.



ASPIDIUM FILIX-MAS.

A.—Median longitudinal section of rhizome (nat. size).

st, stem; b, base of leaf; b', base of young unfolded leaf; a, apex; g, trace of fibrovascular bundle.

B.—Portion of an old rachis with a bud, k, and its roots, w.

C.—Section of a similar base.

D.—Rhizome with leaves cut off at base.

E.—Rhizome with the cortical tissue removed, showing the network of fibrovascular bundles, and the bases of the bundles going from the edges of the meshes into the leaves.

F.—Portion of the fibrovascular network dissected and magnified.

and ground tissue, there is a third very complicated tissue system, the fibrovascular.

The epidermis consists here of a single layer of closely packed, rather thick-walled cells, the walls of which are brown, and to this the scales are attached. The ground tissue consists of cells which contain protoplasm, are about as broad as long, and which are generally loosely packed, with air spaces between them—of cells, in fact, which are very little altered from the original type of *Protococcus*. Such cells are called parenchymatous, and a tissue composed of them is called parenchyma. On the other hand, cells which become much longer than broad, and which fit closely into one another, are called prosenchymatous, and make up a tissue called prosenchyma; while cells whose walls become hard and woody are spoken of as sclerenchymatous, and make up sclerenchyma. The outer part of the ground tissue in Fern, immediately below the epidermis, is prosenchymatous and sclerenchymatous, and appears dark brown in section. In some Ferns, *e.g.* Bracken, bundles and strands of sclerenchyma are scattered throughout the ground tissue; and this is also sometimes the case in flowering plants; for example, the gritty sensation felt on biting through a pear is due to bundles of sclerenchyma in the flesh. The parenchymatous cells of the ground tissue have pitted walls, like those of the cortex of *Fucus*.

The fibrovascular bundles run somewhat irregularly through the stem. They branch and anastomose, and give off smaller bundles to the leaves. In *Aspidium* they form a network, with the branches to the leaves given off from the edges of the meshes. They may be distinguished by the naked eye, and easily dissected out in a piece of rhizome which has been macerated by boiling in dilute hydrochloric acid.

By a careful comparison of transverse and longitudinal sections, it has been made out that the fibrovascular bundles have the following structure. It is somewhat easier to follow in Bracken, which is also easier to cut than *Aspidium* and most other Ferns, but the main points may be made out in any Fern which is handy.

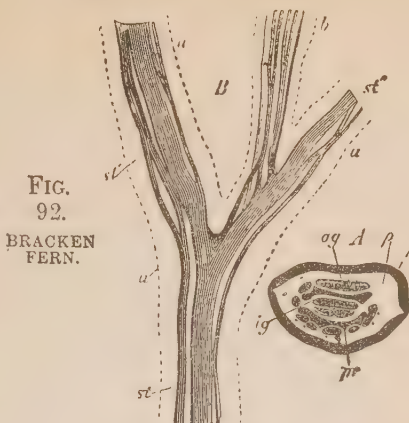
The bundles are elliptical in shape, and composed of two parts:—

1. Wood or Xylem.

2. Bast or Phloëm.

The wood is the middle of the bundle, and is surrounded by the bast, this being known as the concentric arrangement of wood and bast.

Wood and bast are both composed partly of parenchymatous cells. In addition to this the wood consists of large elongated fusiform cells known as tracheïdes (*trachea* = a vessel, *eidos* = like). In transverse section these appear not round, but polygonal, owing to mutual pressure. The walls are thickened, either in transverse bars giving rise to



A.—Transverse section of rhizome (nat. size); *r*, external sclerenchyma; *pr*, internal band of sclerenchyma; *p*, parenchyma; *ag*, and *ig*, fibrovascular bundles.

B.—Longitudinal section of the same, showing the course of the fibrovascular bundles; *a*, outline of cortex; *st*, stem; *st'*, and *st''*, branches; *b*, base of a leaf.

C.—Transverse section of a quarter of a fibrovascular bundle of Bracken, much magnified; *P*, parenchyma of the ground tissue; *sg*, bundle sheath; *b*, bast fibres; *sp*, openings of sieve tubes; *g*, openings of scalariform wood tracheïdes; *S*, opening of a spiral tracheide; *K*, pits on walls of wood cells.

the ladder-like markings of the scalariform (*scala* = a ladder) tracheides, or in a spiral round the cells, in the smaller, rounder, spiral tracheides. They are changed into wood, or lignin, and the cell contents entirely disappear, so that a wood cell is no longer living, but is only the skeleton of a once living cell. The spiral tracheides are fewer in number, and may be found at the two foci of the elliptical bundle.

The bast has, in addition to parenchyma, sieve tubes. These are formed each from a row of cells. They are thin-walled and particularly rich in protoplasm. The oblique partitions between the original cells, and also sometimes the side walls, are marked by pits or perforations, through which the protoplasm is continuous. The perforated portions are known as sieve-plates. Thus a sieve tube is formed by the fusion of a row of cells, and as such is called a vessel. Bast also consists in part of elongated thick-walled fibres.

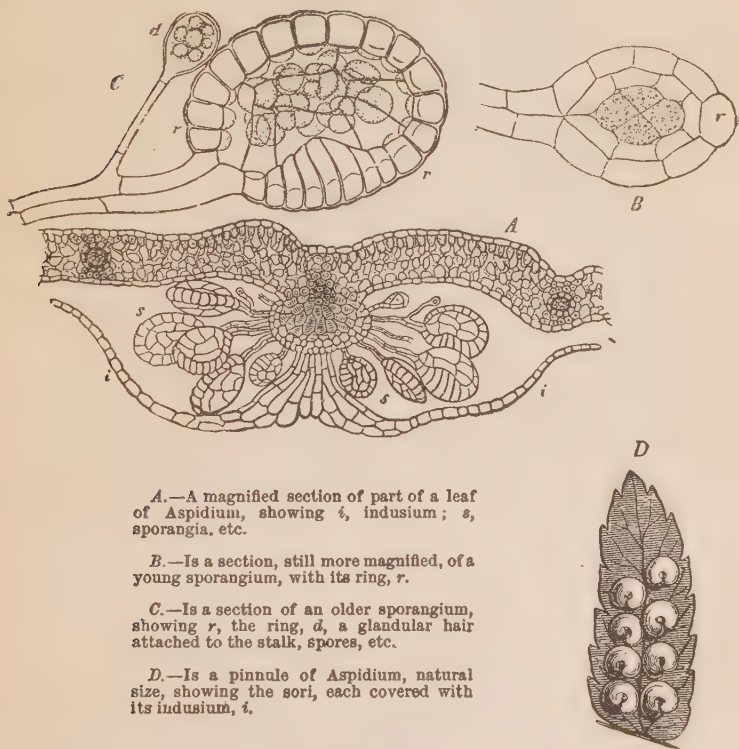
The bundles as above described are surrounded by a double sheath. The outer, composed of lignified, closely packed cells, is the bundle sheath, and the inner, thin-walled and very rich in starch, is the bast sheath.

The stem goes on growing at its apex; consequently the youngest part of the stem is immediately behind the apex. Very young cells are all alike, and the differences described above only appear as they grow older. At first all the cells are thin walled, rich in protoplasm, and capable of division. They are then said to be meristematic. The meristematic tissue behind the apex is constantly being added to by divisions of the apical cell. This, in the Fern, as in Moss, has the shape of a three-sided pyramid, with a dome-shaped base turned outwards. It constantly divides by partitions formed in regular sequence parallel to the three sides of the pyramid. These new cells are constantly being added to the meristem, out of which, on the other hand, by division and modification, the fixed tissues are constantly developing. The roots end in a similar apical cell, but here partitions arise parallel to the base of the pyramid, as well as to its sides, so that a tissue is formed outside the apical cell to protect it. This is the root-cap.

The structure of the roots and leaves of ferns is essentially the same as that of the same organs in flowering plants, so that details concerning this may be postponed.

The leaves consist of a stalk or rachis, and of flattened leaflets, called pinnae, with subdivisions called pinnules, and are

FIG. 100.



A.—A magnified section of part of a leaf of *Aspidium*, showing *i*, indusium; *s*, sporangia, etc.

B.—Is a section, still more magnified, of a young sporangium, with its ring, *r*.

C.—Is a section of an older sporangium, showing *r*, the ring, *d*, a glandular hair attached to the stalk, spores, etc.

D.—Is a pinnule of *Aspidium*, natural size, showing the sori, each covered with its indusium, *i*.

more or less compound in different Ferns. The three tissues are continued into the leaves, where the cells of the ground tissue, and even of the epidermis, contain chlorophyll. The leaves develop slowly, and continue their growth for a long time.

Reproduction.

On the under side of some of the fronds, brown lines or patches may be seen. In *Aspidium* these patches are kidney-shaped, and are arranged in a double row on the under side of the pinnules. The form and arrangement varies, however, in different ferns. These patches are called sori, and consist of a number of little organs, containing spores, and therefore called sporangia, which in *Aspidium* are attached to a vein. An umbrella-like membrane, the indusium, springs also from the vein and covers the sorus.

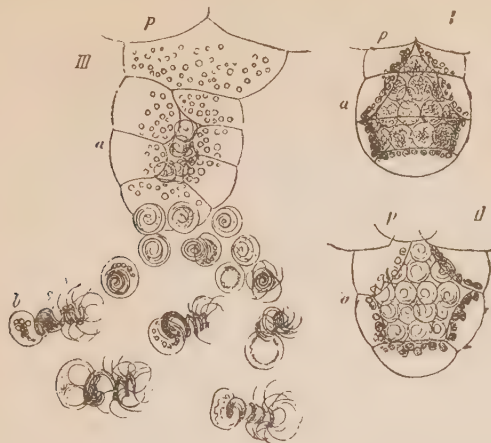
Each sporangium has a stalk, and is the shape of two watch-glasses put together, with a ring of thickened cells, the annulus, where they join. The annulus tends to straighten itself out, and thus ruptures the ripened sporangium, and scatters the contained spores. These, falling on a damp surface, at once germinate.

They do not, however, at once produce a new Fern plant. Each spore is covered by two coats, a rough brown exospore, and a thin delicate endospore. The endospore grows out, bursting the exospore, into a hypha-like tube, which divides rapidly so as to form a flat expanded body, called the prothallus or prothallium, which is always small compared with the original Fern plant. Owing to the rapid expansion of cells behind the growing point, this comes to lie in a hollow, and thus the prothallus becomes heart-shaped. The central part behind the growing point is several layers thick, and is called the cushion. The rest remains thin, and is very rich in chlorophyll. Root-hairs are given off from the under side.

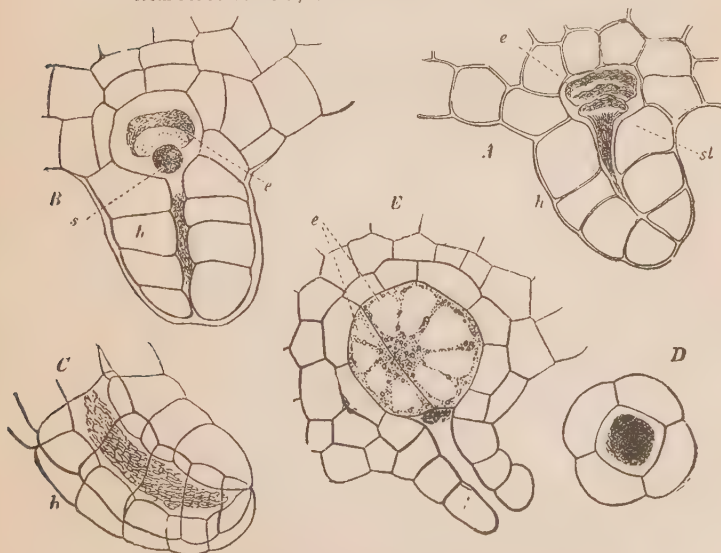
Reproductive organs of two kinds, antheridia and archegonia, similar to those of Moss, are borne by the prothallus.

The antheridia are round, and are found amongst the root-hairs towards the back of the cushion. The archegonia are partly imbedded in the front of the cushion. They are similar to those of Moss, but more cylindrical in shape. As in Moss, ciliated antheridzoids are freed from the antheridia, and coalesce

FIG. 101. REPRODUCTIVE ORGANS OF FERN.



I, II, III.—Longitudinal sections of Antheridia at successive ages:
p, tissue of prothallus; *a*, antheridium; *s*, antheridzoid emerging
 from the mother cell, *b*.



A, B, C, E.—Longitudinal sections of archegonia; D, transverse
 section; *e*, oosphere; *s*, lowest canal cell; *h*, neck; *sl*, mucilage
 formed by degeneration of the canal cells.

with the oosphere at the base of the archegonium, to form an oospore. It is from the oospore that a fresh Fern plant, with root, stem, and leaves, is produced. The oospore divides and the upper half produces a mass of cells, called the foot, which remains embedded in the cushion, and which serves to connect the young Fern with the prothallus, from which it for some time derives food. The lower half divides into two cells, one of which gives rise to the rhizome, and the other to the first root of the new Fern. The rhizome soon produces a first leaf, often unlike the succeeding ones, which grows up between the lobes of the prothallus, and begins to manufacture food for the young plant.

Ferns, then, like Mosses, present distinct alternation of generations. The sporophore or spore-bearing generation begins with the oospore, includes the whole of what is ordi-

FIG. 102.



Young plant of *Capillus-Veneris* in connection with the prothallus.—*b*, first leaf; *p*, prothallus; *h*, root-hairs of prothallus; *w*, first root of the young Fern.

narily known as the Fern plant, and ends with the formation of spores—whence its name. The oophore generation begins with the spores, includes the prothallus with the reproductive organs, and ends with the oospore. A comparison with the life-history of a Moss shows that while in Moss the oophore was the more conspicuous and highly developed part—the sporophore appearing as a mere appendage—in the Fern this is reversed. The oophore generation of a Fern includes only the relatively insignificant prothallus, while the sporophore forms the highly developed Fern plant.

Ferns, however, like Mosses, often reproduce themselves in a purely vegetative manner. For instance, the older parts of the rhizome often die away, leaving the branches as separate individuals. Also in many Ferns buds arise from the ground tissue of the leaves, and grow out in fresh individuals, which are eventually set free.

Physiology.

Ferns contain chlorophyll, and in presence of sunlight are able to manufacture their own food. They obtain carbon dioxide and water vapour from the air, and the roots absorb from the soil water containing a variety of substances in solution. These processes will be described in more detail in connection with flowering plants.

The most highly developed Pteridophyta have peculiarities which must now be noted.

In *Osmunda Regalis*, etc., it is only certain specially modified fronds which bear spores. These fertile fronds have hardly any ground tissue, and are covered with crowded sporangia.

In *Equisetum*, the Horsetail, a plant intermediate between Ferns and flowering plants, the fertile leaves are collected into a spike quite unlike—in fact appearing at a different time of year (about May) from the sterile branches. This is also noticeable in certain other plants, such as *Lycopodium*, etc.

In some intermediate plants there are often two kinds of prothallia, and even two kinds of spores. Thus *Selaginella* produces large spores, called macrospores, which on germination produce prothallia bearing only archegonia; and also small spores, microspores, which produce small prothallia bearing only antheridia. These prothallia are both very small; in fact, what may be called the microprothallium consists of only a single cell.

Thus it appears that in the highest members of this group there are the following tendencies:—

- (1) For some of the leaves to be specially modified to bear spores, the rest being sterile.
- (2) For the spore-bearing leaves to be collected on special branches.
- (3) For a distinction to arise of two kind of spores, microspores and macrospores, producing two kinds of prothallia, and causing a separation of antheridia from archegonia.

Classification.

The Ferns, etc., are known as Vascular Cryptogams, or Pteridophyta (*Pteris* = a Fern), and this is the highest group of the Cryptogams, of which the classification may be recapitulated as follows :—

GROUP I. **THALLOPHYTES.** Plants without any distinction into stem and leaves, to which belong :—

<i>Algae.</i>	<i>Fungi.</i>
Protococcus.	Yeast.
Spirogyra.	Mucor.
Vaucheria.	Pythium.
Fucus.	Mushroom.

GROUP II. **MUSCINEÆ.** Plants which have no true roots, but which present distinct alternation of generations.

Funaria.

GROUP III. **PTERIDOPHYTA.** Plants having root, stem, leaves, and fibrovascular tissue, and presenting distinct alternation of generations, but without the power of forming seeds.

Aspidium Filix-mas.
Pteris Aquilina.
Equisetum.
Lycopodium.
Selaginella.

PRACTICAL WORK.

Examine any convenient Fern, such as *Aspidium Filix-mas* or *Pteris Aquilina*.

Observe with the naked eye the rhizome, roots, fronds, bases of old fronds, young fronds with their circinnate venation, scales, and, after carefully removing leaves and scales, the flat apex.

Examine the fronds—their rachis, pinnae, sori.

With microscope observe the sporangia and spores.

Divide part of the stem first transversely, then longitudinally.

Observe the tissues with the naked eye, and trace out so far as possible the course of the fibrovascular bundles. Boil a piece in dilute hydrochloric acid, and carefully dissect away the ground tissue.

Make very thin transverse and longitudinal sections, and verify with the high power, so far as possible, the structure described in the text.

The tracheides and sclerenchymatous cells of the ground tissue may be isolated by warming a piece of the tissue gently in potassium chlorate and nitric acid, and teasing out.

Prothalli may be obtained by sowing some spores on damp earth, and keeping them moist and protected from direct sunlight for a few weeks. The young Fern will develop in connection with the prothallus in the course of about three months.

A whole prothallus may be picked off, and mounted bottom upwards.

Observe, with the low power, its shape, structure, colour, cushion, root-hairs; and under a higher power the antheridia and archegonia. The antheridia will be found amongst the root-hairs towards the back of the cushion, and the necks of the archegonia project from the front of the cushion.

If the prothallus be imbedded, sections may be cut through the cushion to show the structure of the archegonia.

PART III.

GENERAL DESCRIPTION OF FLOWERING PLANTS

CHAPTER I.

LIFE-HISTORY OF FLOWERING PLANTS.

Fertilisation.

The account given in the last chapter of the life-history of Ferns, and of the modifications found in plants immediately above the Ferns, leads us very easily to understand the life-history of flowering plants. This is somewhat different in the two divisions.

On examining a Gymnosperm, such as Scotch Fir, we find that it is only some of the leaves which bear spores, the majority being sterile. We also find that the fertile leaves are collected into special spikes or cones, appearing only in early summer. Again, we find two kind of spores. What we have called microspores are here generally called pollen grains, and the leaves bearing pollen grains (microleaves) are called stamens. On the other hand, the macrospores are included in the ovules, which are borne by the carpels (macroleaves). The stamens are collected into special staminate spikes, and the carpels into cones, so that a distinction arises between micro- and macro-branches, and even of micro- and macro-plants, where all the stamens are on one plant, and all the carpels on another. In such a case the distinction which in Mosses and Ferns appears only in the oophore generation, is carried back through the sporophore.

The microspore, or pollen grain, of a Gymnosperm consists at first of a single cell, surrounded by two coats, the extine and the intine, but it soon divides and comes to consist of two, or often of several, cells, corresponding to a prothallium. No separate antheridzoids are formed (compare *Pythium*),

but a tube grows out from the largest cell of the prothallium, here called a pollen tube.

The pistillate cones consist of a number of carpels, each borne in the axil of a bract, and bearing two ovules. The ovules consist of a mass of cells, the nucellus, surrounded by a coating layer, in which there is an opening, the micropyle. There is a short stalk at the end opposite the micropyle, and, under the micropyle, one cell of the nucellus, called the embryo sac, is much larger than the rest. This cell is the macrospore. It germinates without being set free, and forms a macro-prothallium, called here the endosperm. Imbedded in this are several archegonia, or corpuscula, each consisting of several neck cells, and of a large central cell, the oosphere.

The pollen grains are carried by wind to the ovules, the Gymnosperms being wind-fertilised. They have two air-bladders between the extine and the intine, to enable them to float more easily through the air. The pollen tubes described above enter the micropyle of the ovule and grow till each reaches a corpusculum. The nucleus of the pollen tube then appears to pass through its tip, and in some way the fertilising substance is transferred through the neck cells to the oosphere, which becomes an oospore. From the oospore an embryo is developed, which remains imbedded in the endosperm, and the ovule is thus transformed into a seed. A period of rest, varying according to circumstances, is followed by germination, that is, by the continued growth of the embryo into a fully developed plant.

It will now appear that the life-history of a Gymnosperm is essentially the same as that of a Fern. The chief differences are the great reduction of the oophore generation, and the connection of this with the preceding sporophore. The separation of fresh individuals does not take place till the new plant, as an embryo with root, stem, and leaves, is already well advanced in the new sporophore generation. Thus seeds are formed, and this is the great characteristic of the Phanerogamia. The name, signifying "evident union," is, as before stated, not a good one, for it now appears that the union is that of the pollen nucleus with the oosphere, and this is anything

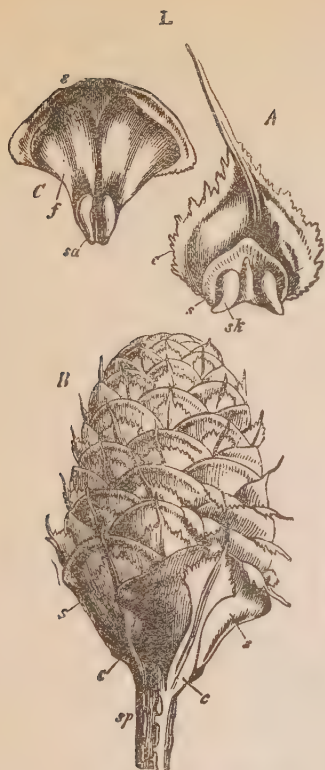
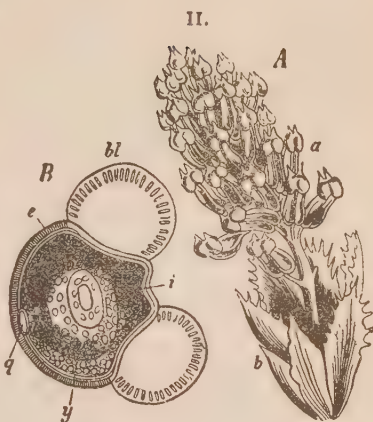


FIG. 103. ABIES PECTINATA.



I.—A, bract; s, carpellary scale (mag.); sk, ovules. B, upper part of carpellary cone; sp, floral axis; c, bracts; s, the much developed carpellary scales. C, ripened carpellary scale bearing two seeds, sa, with their appendages, f (reduced).

II.—A, staminate spike; a, stamens; b, bracts. B, a pollen-grain (mag.); bl, air-bladder; e, extine; i, intine; y, cells of prothallus; g, beginning of pollen tube.

III.

Diagram of ovule of *Pinus* showing fertilisation, k, nucellus.

i, integument.

m, micropyle.

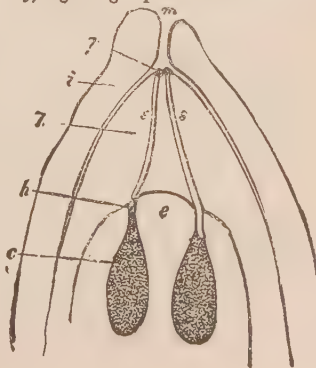
e, endosperm, filling the embryo sac.

o, oosphere.

h, the neck cells.

p, pollen grains applied to the apex of the naked nucellus.

s, s, the pollen-tubes. (After Prantl.)



but evident, having, indeed, been entirely overlooked by the older botanists. It is, on the whole, decidedly less evident than the same process amongst the Cryptogams, whose name signifies "hidden union." We are no better off, however, if we call this the group of flowering plants, for the fertile spikes of *Osmunda* and *Equisetum* are of just the same nature as the cones of firs or even the flowers of Angiosperms.

In the Gymnosperms the ovules are exposed to the air, sometimes, as in Scotch Fir, borne by the carpels; sometimes, as in Yew, borne directly on the axis. Amongst the Angiosperms the carpels form a closed chamber in which the ovules are enclosed. There are also certain variations in the life-history.

The fertile leaves, stamens, and carpels are surrounded by specially modified sterile leaves, which form the calyx and corolla.

The pollen grains, or microspores, often consist to the end

FIG. 104.

Section of ovule of *Crocus*.



funicle; *r*, raphe; *ch*, chalaza;
m, micropyle; *e*, embryo sac;
a, antipodal cells; *o*, oosphere;
s, synergidae.

of only one cell, but the microprothallium, though reduced almost to a vanishing point, is still represented by the formation of a second nucleus in the pollen grain, and the antheridium by the pollen tube and its nucleus.

The embryo sac, or macrospore amongst the Angiosperms, does not form endosperm till after fertilisation, but the macroprothallium is still represented by the formation, in the embryo sac, of a number of nuclei. Three are found at the end under the micropyle, one in the middle, and three at the opposite end, which last are called the antipodal cells, and represent the macroprothallium. The three under the micropyle represent the archegonium; the largest is the oosphere, and the other two are called synergidae.

Pollen grains are carried in various ways to the stigma, where, germinating, they give off pollen tubes, which grow down through the style and ovary to the ovules, enter the micropyle, and fertilise the oosphere. A mass of cells completing the endosperm is then formed within the embryo sac, and an embryo develops from the oospore. Thus the ovules are transformed into seeds.

PRACTICAL WORK.

Gymnosperms.

Examine staminate cones of *Pinus*, which are ready about May or June. Bisect one longitudinally and observe the axis, bearing rows of staminate leaves. Take off one stamen; notice the stalk or filament and the two pollen sacs on the under side. Wet some pollen grains in spirit, mount in glycerine, and observe as above.

The young carpellary cones, which are small, are found close to the apex of the young branches. They are usually in the receptive state, with scales slightly separated, about the beginning of June, and are then reddish brown. They should be hardened in alcohol, and may be thus preserved for months, but must be transferred to a mixture of equal parts of alcohol and glycerine for twenty-four hours before being used, to restore their consistency. Make out the structure by dissecting the cone with needles, observing, meanwhile, with a lens, to see the bract, the carpel with its midrib, and the two ovules. Notice the prolongations of the covering of the ovule. Pollen, brought by wind, slips down the carpels, and, guided by the midrib, comes between the above. Later they curve inwards, and carry the pollen into the micropyle. In Scotch Fir fertilisation does not take place for about thirteen months after this, so that to observe the result of fertilisation it is necessary to examine the succulent green cones of the previous year. The scales of these should be laid separately in alcohol to harden, and be then examined. The bracts are now relatively small, the carpels have no longer a midrib, but show already two unripe seeds, and signs of the "wings" which separate off with the seeds. Separate off the unripe seed with the point of a needle, cut longitudinal sections, and observe the integument, micropyle, nucellus, endosperm, archegonia, and pollen tubes, as above described.

The old brown cones of the year before last are also present, and consist of widely separated lignified carpels, from which the seeds have dropped out.

Angiosperms.

Take the ovary of tulip (or of any plant of the species *Lilium*), and cut transverse sections. Treat these with a half-and-half mixture of alcohol and glycerine, being careful that the ovules do not drop out. Let the alcohol evaporate, and transfer to pure glycerine. Observe the position of the ovules, and their structure as above described.

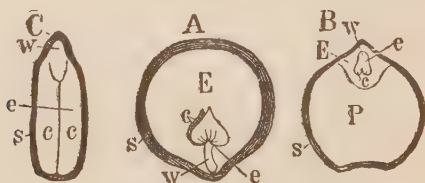
Cut median-longitudinal sections of the stigma and style of such a long-styled plant as Evening Primrose. Pollen grains can be seen on the stigma, and may often be observed to penetrate the tissues. Gently boil the sections in dilute glycerine, and again examine. The pollen tubes may be traced by their densely granular contents through the now transparent tissues of the style.

CHAPTER II

THE SEED.

AFTER fertilisation the development of the ovule is as follows :—The two coats of the ovule coalesce more or less completely to form the skin or testa of the seed, in which one can often distinguish two layers, *e.g.* in Almond. Sometimes a third coat, the arillus, grows up round the seed, after fertilisation. It is an arillus which forms the pink fleshy cup round the seed of Yew, and the imperfect arillus of nutmeg gives us mace.

FIG. 105.



Sections of ripe seeds.

A.—*Nux vomica*, showing *E*, endosperm.

B.—*Piper*, showing both endosperm, *E*, and perisperm, *P*.

C.—Almond, devoid of endosperm; *S*, testa; *e*, embryo; *w*, its radicle; *c*, *c*, its cotyledons.

The nucellus usually disappears, though it occasionally persists, forming what is called perisperm, as in the seed of *Piper*. Much more frequently the endosperm, or albumen, persists, as in *Wheat*, *Euonymus*, etc. Often, however, the endosperm is all absorbed by the growing embryo, which thus occupies the whole of such exalbuminous seeds as *Pea* and *Bean*.

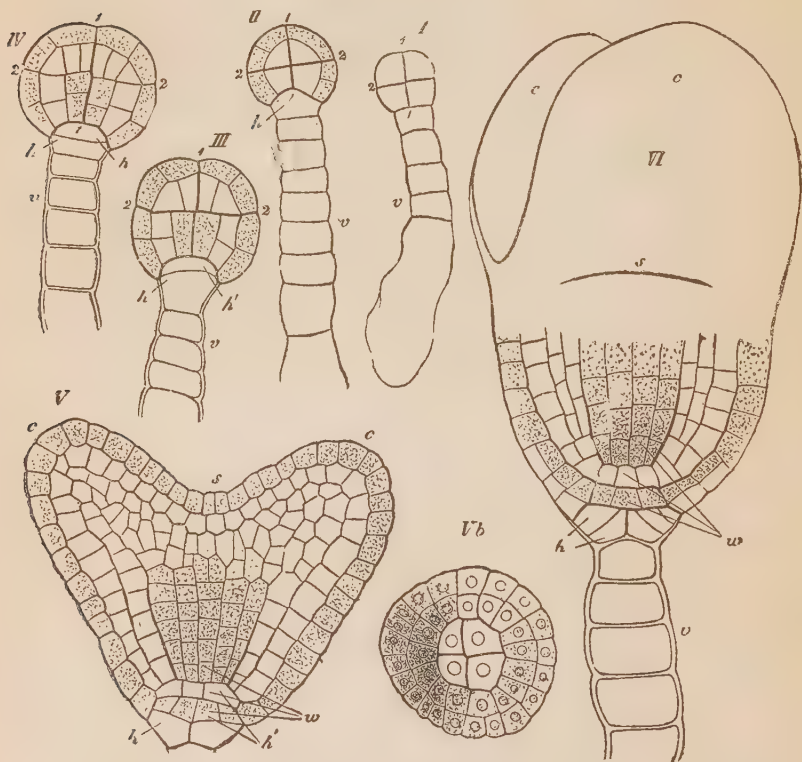
The embryo is derived from the oospore alone. Thus every flowering plant consists in its earliest stage of one single cell, as *Protococcus* does throughout its life. The development of the oospore varies greatly in different cases. In such a typical dicotyledon as *Shepherd's Purse*, it may be traced through the following stages. The oospore divides transversely. The upper half, towards the micropyle, forms a string of cells, known as the suspensor. The lower half, which is thus lowered into the endosperm, from which it absorbs food, forms the embryo. It divides repeatedly, to form in the first instance a round mass of cells. These are only alike for a very short time. Very soon divisions parallel to the surface cut off an external layer, and soon afterwards longer, more closely packed cells can be distinguished in the interior. Thus the three tissue systems of the mature plant are very early indicated. Being only slightly differentiated, and still capable of active division, they cannot be denoted by the same names as the mature tissues; but the epidermoid layer is called the dermatogen, the central cells the plerome, and the intermediate ones the periblem. As this differentiation proceeds the embryo itself becomes bilobed at its free end, and develops the growing point of the stem between the lobes, and that of the root internally at the opposite end. The lowest cell of the suspensor (hypophysis) shares in the formation of the root.

Notice that the embryo of a highly developed plant such as *Shepherd's Purse* repeats in its own history the stages of development which may be observed in the lower plants. It is at first unicellular, like *Protococcus*; it then passes on to a stage in which it consists of a thallus; the thallus becomes bilobed, like that of *Fucus*; and finally stem and root arise.

The fully formed embryo consists of a first root or radicle, a first stem shoot or plumule, and two seed leaves or cotyledons. Before germinating it passes through a period of rest varying according to circumstances.

In the Monocotyledons only one seed leaf is developed, whence the name, but the formation of the embryo is essentially the same as that described above. The embryos of

FIG. 106.



Stages in the development of the embryo of Shepherd's Purse.
v, suspensor; *h*, hypophysis; *c*, cotyledon; *w*, growing point of root;
s, growing point of stem.

Gymnosperms produce from two to fifteen cotyledons, and they turn green even in the dark.

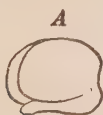
The following "debtor and creditor account" between

the ovule and the seed will summarise what has been said above.

OVULE.	SEED.
Funicle.	Raphe, beginning at the scar, and ending at the chalaza or spot.
Two coats, the primine and secundine.	One coat, the testa; sometimes an arillus.
Micropyle.	A small hole.
Nucellus.	Generally disappears; occasionally persists as perisperm.
Embryo sac.	Endosperm, which sometimes persists, sometimes disappears.
	Oospore, giving rise to embryo with { radicle. plumule. 1, 2, or more cotyledons.
Antipodal cells.	
Oosphere.	

From what has been said, it appears that the radicle will always point to the micropyle, and the plumule to the opposite end of the embryo sac, *i.e.* to the chalaza or spot. Hence in seeds derived from orthotropous and anatropous ovules the embryo is straight, and in those derived from campylotropous ovules, it is curved. When the radicle curves over the edges of the cotyledons, as in Pea, it is accumbent; when over the back, as in Hemp, it is incumbent.

FIG. 107.



A.—Accumbent embryo of Pea.



B.—Incumbent embryo of Hemp.

Germination.

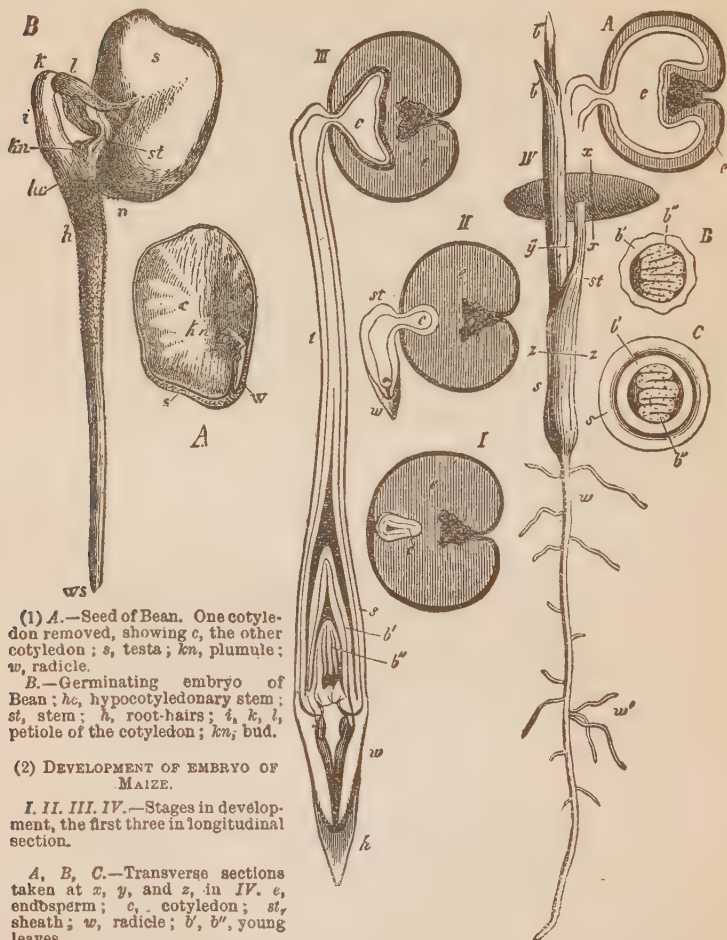
After a period of rest the seed germinates. The endosperm, if present, or otherwise the cotyledons, take up water, swell, and burst the testa. In dicotyledons the part of the axis below the cotyledons lengthens considerably, so as to push the radicle out of the seed. The radicle grows rapidly, and puts out branch roots while the plumule and cotyledons are still within the testa. If the cotyledons are thick and

fleshy, as in Bean, they remain in the seed, and supply the growing plant with food till they are exhausted, when they

(1)

FIG. 108.

(2)



(1) *A*.—Seed of Bean. One cotyledon removed, showing *c*, the other cotyledon; *s*, testa; *kn*, plumule; *w*, radicle.

B.—Germinating embryo of Bean; *hc*, hypocotyledonary stem; *st*, stem; *h*, root-hairs; *k*, *l*, petiole of the cotyledon; *kn*, bud.

(2) DEVELOPMENT OF EMBRYO OF MAIZE.

I. II. III. IV.—Stages in development, the first three in longitudinal section.

A, B, C.—Transverse sections taken at *x*, *y*, and *z*, in *IV*. *e*, endosperm; *c*, cotyledon; *st*, sheath; *w*, radicle; *b'*, *b''*, young leaves.

decay away. Their petioles lengthen so that the plumule emerges, becomes erect, grows up into the stem, and unfolds

its foliage leaves. On the other hand, in many cases the cotyledons are drawn out of the seed, are carried up by the lengthening of the axis, expand, turn green, and form the first foliage leaves, generally however unlike those formed later, *e.g.* Beech, Mustard, etc. If the seed contains endosperm, the cotyledons do not emerge till it is all absorbed.

As the axis enlarges both stem and root put out branches in regular order behind the apex. Later on adventitious branches are often formed. In some cases the primary stem and root die soon after germination, or at the end of the first period of growth, and the future growth of the plant is continued by branches, tubers, etc.

In Monocotyledons the embryo is pushed out of the seed by the lengthening of the cotyledon itself, which here forms a sheath to the plumule. The upper part of the cotyledon remains in the seed till the endosperm, which in this class of plants is relatively large, is all absorbed, and then it generally develops into the first green leaf. The primary root here always remains small. The stem sometimes lengthens and bears foliage leaves, as in Maize, or very often remains short, and bears scaly leaves, forming a bulb, as in Onion.

PRACTICAL WORK.

In the exalbuminous seed of Pea or Bean (derived from campylotropous ovule) observe the micropyle, scar, raphe, and chalaza. Tear off the testa, and examine the curved embryo, consisting of two fleshy cotyledons, a plumule already showing the beginnings of the first foliage leaves, and the relatively large accumbent radicle.

Similarly observe Almond or Hazel, where the embryo is straight, and the seed is derived from an anatropous ovule; and Yew (where also note the arillus), or the seeds of Stinging Nettle, in which cases the ovules were orthotropous. The seeds must be previously soaked for two days. The incumbent radicle is very clearly shown in the embryo of Hemp.

To observe the stages of the formation of the embryo, tear open young fruits of Shepherd's Purse, and take out the ovules. Place them on a slide in water, prick them, cover with a coverslip, and gently press the embryo out. Repeat the process with ovules of different ages.

To observe germination, sow half a dozen or so of the seeds to be studied in nice earth or damp sand, twice a week for five or six weeks (the time necessary will vary with the rate of growth of the plant in question). Dig up, wash the earth off the roots, and compare the series.

CHAPTER III.

CROSS-FERTILISATION.

IN describing the process of fertilisation, it has already been stated that, as a preliminary step, pollen grains must be carried to the stigma. They are so carried chiefly in two ways:—

- (1) By wind, when the plants are said to be wind-fertilised or anemophilous.
- (2) By insects, when the plants are said to be insect-fertilised or entomophilous.

Experiment shows that stronger seeds and new plants are produced when the pollen of one flower is carried to the stigma of another. This is known as cross-fertilisation, and no part of botany is more striking than the extraordinary adaptation of the structure of flowers to secure this end. Of this a very few examples, taken from an almost unlimited number, will now be described.

When the plants are wind-fertilised, which is the case amongst the cereals and many of the forest trees, we find that amongst trees the flowers are usually developed before the leaves or while these are still very small and young, and unable to interfere with the free scattering of the pollen. In the cereals the pliancy of the stalk effects the same purpose. Also in these plants the calyx and corolla are small and often defective, so as to offer little obstruction, while the stamens have long, thin filaments and versatile anthers, *e.g.* Grass, or produce large quantities of very fine, light pollen, *e.g.* Fir. The stamens are often in one flower and the carpels in another. Such plants are called *diclinous*, *monoecious* if the

staminate and pistillate flowers are found in one plant, dioecious if they are on different plants. Or perhaps, as in Grasses, though the stamens and carpels are in the same flower, they are not ripe at the same time.

It is, however, amongst flowers whose fertilisation depends upon insects that we find the most wonderful contrivances, and here they are so varied that it is difficult to know which to describe.

As amongst wind-fertilised plants, there is a large class with stamens in one flower and pistil in another, *e.g.* *Campion*.

Again, many other flowers are practically diclinous, for the stamens ripen and scatter their pollen either before the pistil of that flower is ripe, when the flower is called *proterandrous*, like the *Compositae*, *Umbelliferae*, etc., or after the pistil has become mature and been fertilised by pollen from another flower, when the flower is *proterogynous*, like *Arum*. This condition, where stamens and carpels are not ripe at the same time, is known as *dichogamy*.

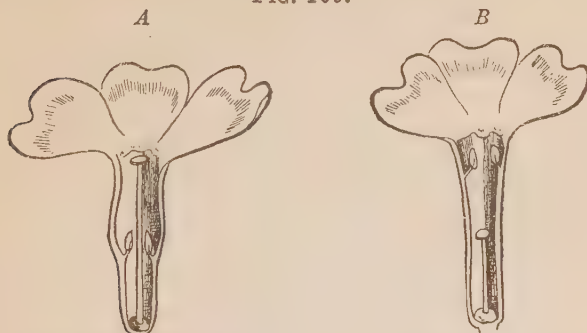
In some cases the pollen is inactive, if it falls on the pistil of the same flower, so that here too the plants are practically diclinous.

The most interesting examples are those in which the structure of the flower is so adapted to the insects which visit it as to bring about cross-fertilisation. These mechanical contrivances are naturally very varied. Probably the colour and markings of the petals, and odours, all serve to attract or guide insects, and the secretion of honey by the nectaries certainly serves this purpose. Notice that anthers always split on the side towards the nectaries, and are introrse or extrorse according to the position of these.

A somewhat common contrivance is known as *dimorphism*, of which an example is found in *Primrose*. In the "pin-eyed" *Primrose* the style is long, and the stamens are inserted on the corolla half-way down its tube, so that self-fertilisation is quite impossible. In the "thrum-eyed" flower the stamens are inserted at the top of the tube, and the style is short.

When an insect visits the flower in search of the honey which collects at the bottom of the tube, it gets dusted by the

FIG. 109.



A.—Section of "pin-eyed" Primrose.

B.—Of "thrum-eyed" Primrose.

stamens of one flower in the exact place where it rubs against the pistil in another, and so cross-fertilises the flowers.

Again, in the Violet and Pansy the arrangement is as

FIG. 110.

A.—Section of flower of Violet.

B.—Showing pistil and stamens.

C.—Enlarged stigma and style.

l, sepals.

c, petals.

cs, pouch formed by back petal.

a, anther.

f, filament.

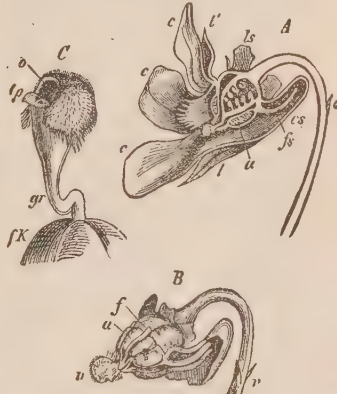
fs, nectary.

v, stalk.

n, stigma.

lp, the stigmatic lip.

o, the opening of the hollow style.

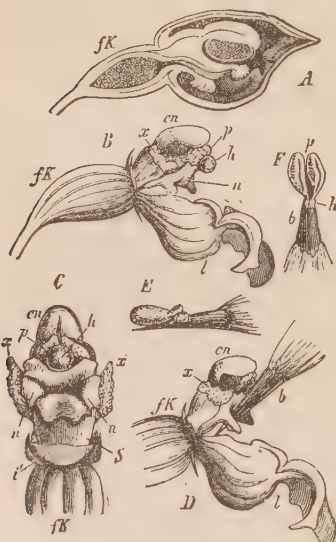


follows:—The stamens are placed below the pistil, so as to prevent self-fertilisation. Two back stamens have nectaries,

which hang down into the pouch formed by the back petal. They secrete honey, so that the tube becomes full of a mixture of honey and pollen. An insect pushing its trunk down into the tube to obtain honey gets it dusted with pollen. On leaving the flower the stigmatic lip is shut up, so that the flower is not self-fertilised, but on entering another flower the lip is opened and pollen is rubbed off on to it, and thus cross-fertilisation ensues. In the event of a failure of cross-fertilisation the cleistogamous flowers, mentioned above, secure self-fertilisation (Fig. 110).

The Orchidaceae are particularly rich in contrivances to secure cross-fertilisation. For instance, in *Epipactus*, the posterior petal, which, owing to the twisting of the ovary,

FIG. 111.



EPIPACTUS.

A.—Section of gynostemium.

B.—Flower with the perianth removed, except the labellum.

C.—Front view of gynostemium, perianth entirely removed.

D.—Same as *B*, but with pencil point inserted.

E, side, *F*, front, view of pollinia as removed by the pencil point.

cn, gynostemium.

fk, ovary.

p, pollinia.

x, staminodes.

h, rostellum.

n, stigma.

l, labellum.

b, pencil point.

hangs down in front, is hollowed out into a receptacle for honey. The stigma forms a disc just above this, and the single fertile anther is attached just above that. Part of the stigma forms the rostellum, a little sticky ball.

If the trunk of an insect be introduced into the nectary of the labellum in the direction shown by the pencil point in Fig. 110, it will press slightly against the rostellum. If it is then withdrawn the rostellum adheres, and is drawn out, bringing with it the pollinia or masses of adherent pollen. These have elastic, glandular stalks, and adhere with wonderful force. They shrink up a little, so that when the trunk is inserted into another flower, instead of being returned to their former position they come in contact with the sticky stigma, to which they adhere.

The above examples must suffice here, but the student is recommended to examine flowers carefully, to observe hundreds of other contrivances equally wonderful.

Cross-fertilisation, though the rule, is not always effected. There are inconspicuous flowers, such as Duckweed and Groundsel, which do not attract insects, and which are, as a rule, self-fertilised.

It is interesting to compare different species of the same genus, where some are always cross-fertilised, others sometimes cross- and sometimes self-fertilised, and others again generally self-fertilised. For instance, take the genus *Geranium*. In all these there is a syncarpous pistil, and two whorls of five stamens each. In Meadow Crane's Bill (*Geranium Pratense*) which has large, dark-blue flowers, the stamens all shed their pollen before the pistil is ripe. First five stamens erect themselves, and stand close to the immature stigma till they have shed their pollen. They then fall back, and their places are taken by the five other stamens. Finally, when all the pollen is shed, the pistil itself ripens, and the stigmas expand. This flower is evidently incapable of self fertilisation, and, being dependent on the visits of insects, the use of the large coloured perianth is apparent. The Mountain *Geranium* (*Geranium Pyrenaicum*) is also blue, but about half the size of the above. Here the stigmas unfold while the second series of stamens are shedding their pollen, so that self- and cross-fertilisation are equally possible. In Dove's-foot *Geranium* (*Geranium Molle*) the flowers are paler, and

still smaller, and the pistil matures before the second set of stamens. Finally, in the small flowered *Geranium* (*Geranium Pusillum*) the pistil matures before any of the stamens, so that it must always be self-fertilised.

Some flowers have arrangements to secure self-fertilisation only in the event of a failure of cross-fertilisation. Thus *Myosotis Versicolor*, when it first opens, has the pistil projecting from the corolla tube, ready to be cross-fertilised by the first insect which alights on the flower; but if this does not take place, the corolla gradually elongates, carrying the epipetalous stamens up above the pistil, to effect self-fertilisation.

PRACTICAL WORK.

To compare the results of self- and cross-fertilisation requires a series of experiments. The genus *Primula* is a good one to try. Secure the plants from the visits of insects by covering them with muslin, and artificially dust the stigmas of certain plants with pollen from the same, and of others with pollen from a different flower. Sow the self- and cross-fertilised seeds in pots in pairs, and, when they grow, measure and compare the lengths of the seedlings.

Examine carefully, and draw vertical median sections through Primrose, Violet, and Orchid.

Similarly observe the structure at short intervals from opening, of other flowers, such as White *Lamium*, Sunflower, Loosestrife, *Aristolochia*, etc.

CHAPTER IV.

HISTOLOGY OF FLOWERING PLANTS.

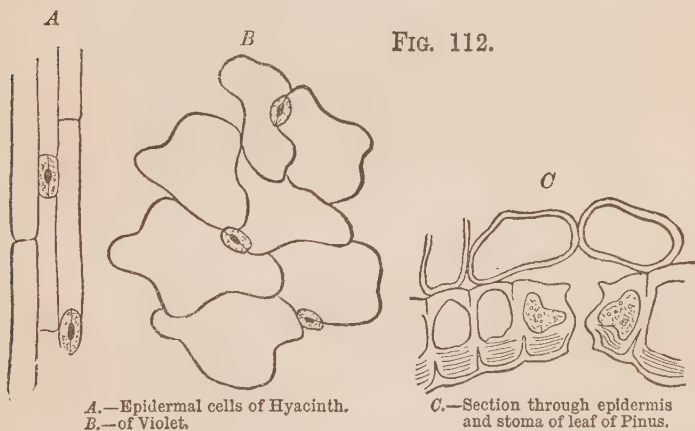
WE have seen that the embryo already consists of three tissues, which, however, are still capable of division. As the plant develops, the dermatogen becomes modified into epidermis, the periblem into ground tissue, and the plerome into fibrovascular tissue and pith, so that flowering plants consist of the same tissue systems as the Fern. In flowering plants the growing point both of stem and root consists of a number of meristematic cells; there is no single apical cell. By the active division of the meristem new tissue is constantly being formed, which is gradually modified, as it grows older, into the permanent tissue systems, which, as a rule, are no longer capable of division.

The Epidermis.

The epidermis of flowering plants consists, in all but a few exceptional cases, of a single layer of cells, which are closely packed, and somewhat thick-walled. The cellulose of the outer, and sometimes of the side-walls, is changed into cutin, a substance allied to cork, which prevents the passage of water. The epidermal cells vary much in shape. In the long narrow leaves of Monocotyledons they are long and narrow, while in the wider leaves of Dicotyledons, their outline is irregular, the cells fitting into one another like the pieces of a puzzle. In all cases, however, they are shallow from without inwards. They contain little protoplasm, and as a rule no chlorophyll. Sometimes the outer wall contains a large amount of silica, as in grasses, or sometimes waxy matter is excreted from the

surface, the "bloom" of fruit being due to such waxy particles.

The plant would thus be enclosed in a complete water-tight envelope but for certain openings between the cells, known as stomata. From the cells of the young epidermis, divisions, known as the mother cells of the stomata, are cut off (*stoma*=a mouth). Each of these divides down the middle to form two cells, the guard cells, which split away from one another, leaving an opening, which is the stoma. The guard cells, when the stoma is open, are crescent shaped, and they alone, of the epidermal cells, contain chlorophyll. The stomata afford a communication between the outer air and the intercellular spaces of the interior, and they serve as ventilating holes. They are found on all parts of a plant except its root, but are most abundant on the leaves, and especially, in land plants, on the under side of the leaves.

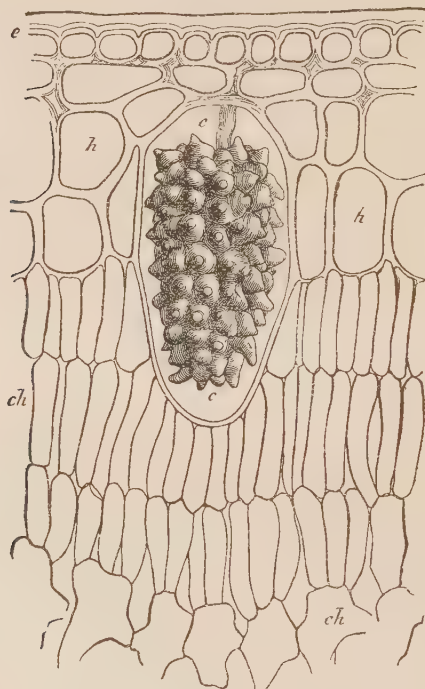


In a few exceptional cases the epidermis consists of several layers of cells; for instance, in the epidermis of the India-rubber plant (*Ficus Elastica*) (fig. 113), and over the aërial roots of Orchids. The epidermis is recognisable by being colourless.

The Fundamental Tissue.

The ground or fundamental system consists as a rule of parenchyma. Its cells are the vitally active cells of the plant. When exposed to light they contain chlorophyll corpuscles.

FIG. 113.

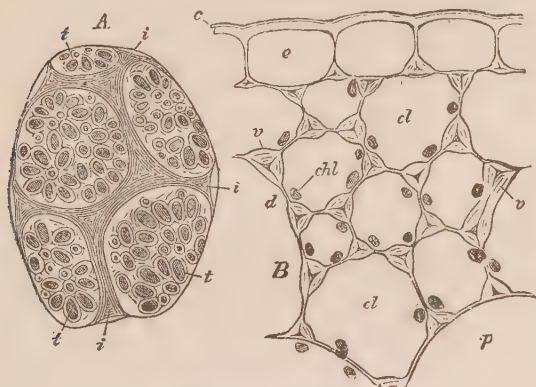
Section through epidermis of *Ficus Elastica*.

e, outer layer; *h*, lower layers of epidermis; *c*, large cell containing cystolith.

In other cases, as in roots and in the interior of stems, their protoplasm is colourless. The walls are very often pitted, and protoplasm seems to be continuous from cell to cell

through the pits. Sometimes part of the fundamental tissue is prosenchymatous, or sclerenchymatous, or even the whole may be prosenchymatous. This is often the case with the ground tissue where it adjoins the other tissue systems. Where it borders on the epidermis, it is sometimes called hypoderma, and where it is in contact with the fibrovascular bundles, it forms the endodermis or bundle sheath. This is especially well marked in roots.

FIG. 114.



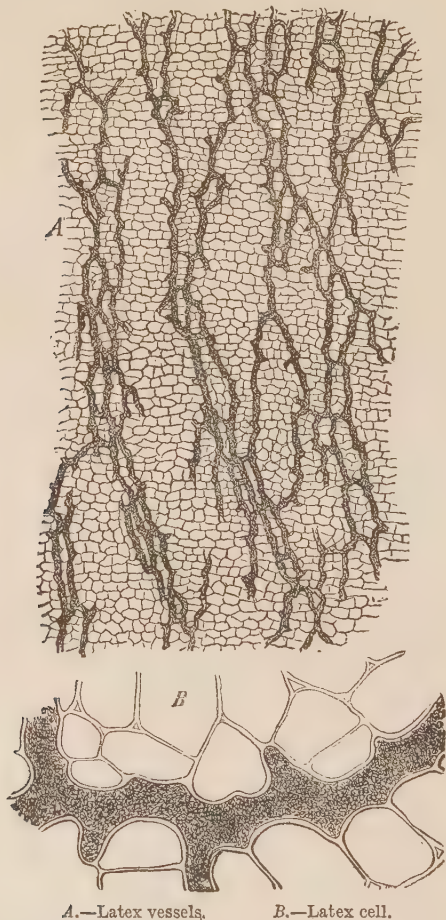
A.—A single hypodermal cell of *Begonia*; *t*, shows the pits in the thickened portions where it adjoined other cells; *i*, the unthickened walls.

B.—A section of a tissue composed of such cells, thickening where several meet (collenchyma); *v*, thickenings; *chl*, chlorophyll corpuscles; *e*, epidermis; *c*, cuticle.

Since the fundamental system is the active part of a plant, it is to be expected that secretions and excretions will occur in it, and this is found to be the case. Many substances are formed by the activity of the protoplasm, which are either stored up as reserve food material (secretions), or deposited and got rid of as useless or harmful to the plant (excretions). These are contained in structures called glands, found in the

ground tissue, and also sometimes in the fibrovascular system. Glands are of three kinds:—

FIG. 115.



A.—Latex vessels.

B.—Latex cell.

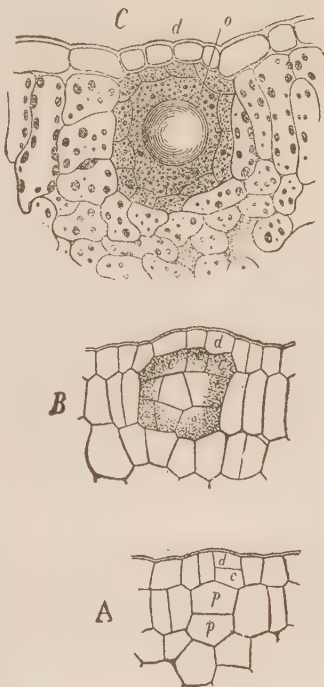
(1.) Substances collect in the interior of certain cells. Such are the crystals, or groups of crystals, found in the parenchy-

matous cells of Monocotyledons; the starch grains which fill up the cells of Potato tubers; the mucilage which collects in certain cells of Mallow; the cystoliths, or masses of minute crystal of chalk found in the lower epidermal cells of the Indiarubber plant collected over an ingrowth of the cell-wall (see Fig. 113); and the peculiar large branched cells found in certain families, *e.g.* the Spurges, which may be observed in the embryo and which grow larger as the plant grows, without dividing. These are called latex cells, because they contain a milky fluid called latex (Fig. 115). It is really a watery fluid, and appears milky because it contains drops of oil, starch grains, caoutchouc, etc. In Maple the latex cells are arranged in rows.

(2.) Secretions are also formed in spaces due to the more or less complete absorption of the cell-walls amongst a number of cells. When the cells which coalesce form rows, the result of fusion is a vessel. Thus latex collects in latex vessels in the Compositae. On the other hand, the oil glands in the skin of Orange are due to the absorption of a whole mass of cells (see Fig. 116).

(3.) Substances may also be formed in intercellular spaces,

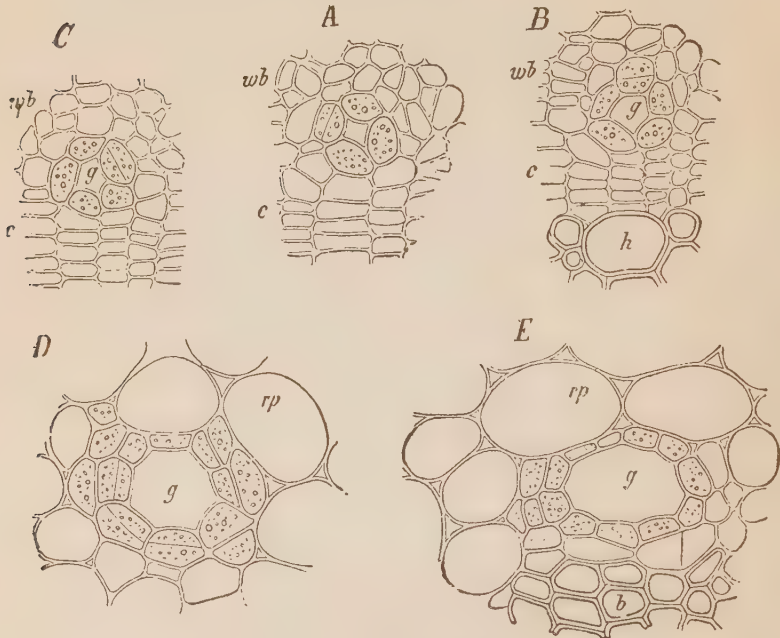
FIG. 116.



A, B, C.—Three stages in the development of an oil gland in the skin of Orange; *d*, epidermal cells; *o*, oil drop; *c*, *p*, *p* are the cells which produce the gland.

due to the separation of cells from one another. Of this nature are the resin ducts of Ivy and *Pinus* (see Fig. 117).

FIG. 117.



Transverse section showing, *A, B, C, D, E*, stages in the development of a resin duct of Ivy; *g*, the intercellular spaces, surrounded by granular secreting cells.

A, B, C are in a fibrovascular bundle, of which *wb* is bast, *c* cambium, and *h* wood; *sp*, parenchyma.

The Fibrovascular System.

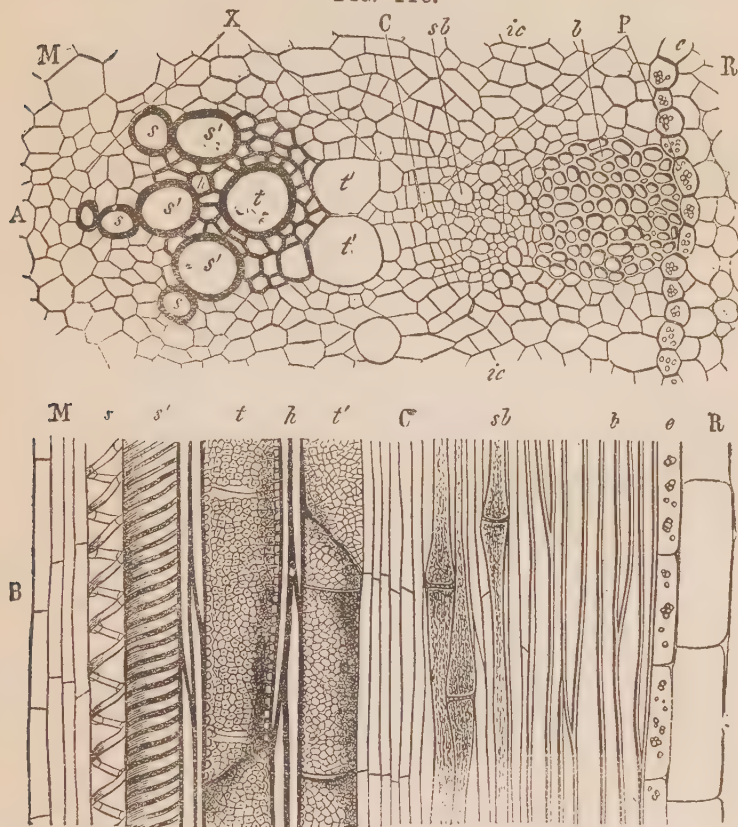
The Fibrovascular bundles of flowering plants, like those of Ferns, consist of wood and bast.

Constituents of the Bundle.

The wood consists of wood parenchyma, of wood fibres, which are long lignified skeleton cells, pointed at the ends similar to the tracheides of Ferns, and also of wood vessels, which are due to the fusion of rows of such tracheides. The

various thickenings of the woody walls of these vessels give rise to spiral and scalariform vessels, and also to pitted vessels,

FIG. 118.



- A.**—Transverse section of an open fibrovascular bundle in the stem of Sunflower; *M*, pith; *X*, wood; *C*, cambium; *P*, phloem; *R*, cortex; *s*, small, and *s'*, large, spiral vessels; *t*, pitted vessels; *t'* pitted vessels in course of formation; *h*, wood fibres; *sb*, sieve tubes; *b*, bast fibres; *e*, bundle sheath; *ic*, interfascicular cambium.
- B.**—Radial vertical section through a similar bundle somewhat simplified, lettered like the former.

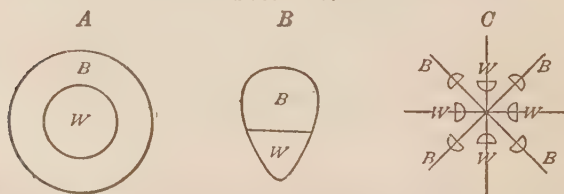
where the whole of the wall is thickened, with the exception of round patches, which remain thin and form the pits.

Such pitted vessels are the commonest vessels found in flowering plants. The fibrovascular bundles originate from the plerome. This forms meristematic procambium and pith, and it is the procambium which passes over into the permanent tissue of the fibrovascular bundles. Very often it does not pass entirely into permanent tissue, but a layer of meristematic cells, the cambium, is left between the wood and the bast. A bundle with cambium is called open; one without, closed. Cambium cells always remain thin walled and rich in protoplasm, and they constantly divide. In shape they are long and shallow from back to front. The bast consists of sieve tubes and bast fibres, similar to those described in Fern, and also contains parenchyma (Fig. 118).

Arrangement of these elements in the Bundle.

In some Monocotyledons the arrangement is concentric, as it is in Fern, but in Dicotyledons and most Monocotyledons we get the arrangement known as collateral, in which wood and bast lie side by side on the same radius of the stem. In a few cases, *e.g.* Cucumber, bast is formed in both sides of the wood, this bi-collateral arrangement being intermediate between the concentric and the collateral. In all roots the fibrovascular bundles are collected into an axial fibrovascular mass, whose arrangement is called radial, masses of wood and bast lying on alternate radii. The cambium, when present, is outside the wood and inside the bast. It is only found in bundles with the collateral and radial arrangements.

FIG. 119.



Diagrams showing arrangement of, *A*, a concentric, *B*, a collateral, wood bundle.
C.—Radial arrangement of wood and bast in roots.

Arrangement of the bundles in the Stem.

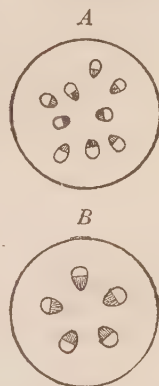
In Monocotyledons the bundles appear in transverse section to be irregularly dotted about, with the wood always towards the centre of the stem. In longitudinal section it is seen that most of the bundles of the stem are in connection with those of the leaf. Traced from the leaf, they enter the stem at a node, bend inwards towards the centre, and afterwards curve out again, thinning as they go, till they end beneath the epidermis. In Monocotyledons with long internodes, such as Grass, the bundles enter horizontally and branch and anastomose at the node, before running down.

In Dicotyledons the bundles in transverse section form a ring with the wood inside. In longitudinal section it appears that the bundles cross and anastomose freely at the nodes, but, as a rule, run straight down from node to node. A bundle, entering from a leaf between two old bundles, bends inwards and then runs straight down to the node next below, where it divides into two. The branches join other bundles, while a fresh bundle from the leaf of that node enters between them. In a few cases bundles are formed which are not in connection with those of the leaf, but which are exclusively cauline, but this is rare. The bundles of the stem are continuous with those of the root.

Increase in Thickness.

The increase in thickness of a bundle depends on the activity of the cambium, so that only those bundles which contain cambium, viz. those of the Dicotyledons, can as a rule increase in thickness. Cambium cells lie between the bast and the wood, and are constantly dividing. Thus, if we consider a cambium cell bordering on the wood, it divides into two; the half next the wood.

FIG. 120.



Diagrams showing, A, the arrangement of the scattered bundles of a Monocotyledon; B, the ringed bundles of a Dicotyledon.

becomes modified into some elements of wood; the other remains a cambium cell, and soon divides again. The cambium cells bordering on the bast behave in a similar manner, so that fresh wood and bast are constantly produced, and the bundle increases in thickness. The bundles in the first instance are separated by bands of parenchyma, which connect the pith and the cortex. These are the primary medullary rays. Secondary medullary rays are often produced within the bundle by the production of rows of parenchyma at intervals from the cambium. The stem would develop unequally and be ruptured but that cambium, called interfascicular cambium, arises between the primary bundles. From this secondary bundles are quickly produced, and thus complete rings of wood, cambium, and bast arise. In arborescent stems the cambium continues each year to add fresh rings of secondary wood and bast. As the stem grows older the wood becomes very much more conspicuous than the bast, and as the wood formed in autumn is often much compressed, so that the openings of the vessels, etc., are small, while those formed in spring are large, annual rings may be distinguished, especially in some kinds of wood, *e.g.* Elm, Oak, etc.

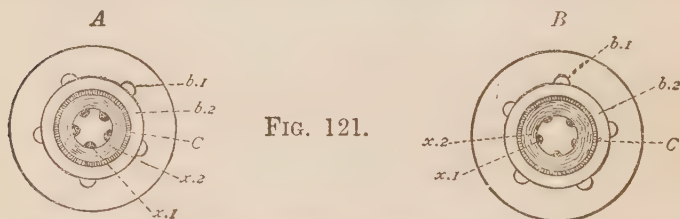


FIG. 121.

Diagrams showing the effect of increase in thickness, *A*, in a stem, *B*, in a root; *b*₁, primary bast; *b*₂, secondary bast; *x*₁, primary wood; *x*₂, secondary wood; *C*, cambium.

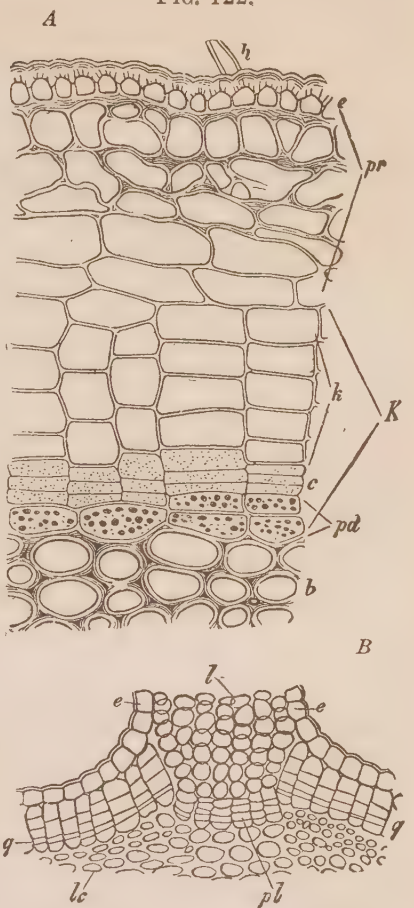
In roots which increase in thickness the cambium layer passes outside the primary wood, and inside the primary bast. By its activity complete rings of wood and bast are afterwards formed, so that an old root can hardly be distinguished from an old stem. It is only in the early stages that the radial arrangement can be easily distinguished. The bundle sheath is always very distinct in roots, because it consists of cells

locked together by the fitting into one another of thickenings of their walls.

Formation of Cork.

The epidermis is incapable of division, except in the case of a few slow-growing plants such as Mistletoe, and is therefore ruptured when the stem increases in thickness. It is replaced by layers of cork, which are formed as follows:—A layer of ground tissue becomes meristematic, and is called cork cambium or phellogen. This produces on its outer border cork cells, which are tabular, parallel to the surface, with their thin walls converted into cork, a substance impermeable to water. Sometimes the phellogen produces in addition parenchymatous tissue interior to itself, called pheloderm. The cork arises sometimes immediately below the remains of the epidermis, sometimes deeper in the ground tissue, or sometimes

FIG. 122.



- A.—Section of cork; *e*, epidermis; *pr*, layers which will form bark; *K*, cork system; *k*, cork cells; *c*, cork cambium or phellogen; *pd*, pheloderm.
- B.—Section through a lenticel of Elder; *e*, epidermis; *q*, phellogen; *l*, cells, and *pl*, phellogen of the lenticel; *lc*, cortical parenchyma.

dermis, sometimes deeper in the ground tissue, or sometimes

even in the bast. Since it prevents the passage of water, all the parts external to it are deprived of their supplies, and die, and thus bark arises. Bark may therefore contain any elements of the plant exterior to the cambium. In some cases the whole of the cortex is thus cut off as bark. The cork itself may also attain a great thickness, as in the Cork Oak.

Special organs, called lenticels, are found in the cork, and replace the stomata of the epidermis. They are formed below old stomata, and consist of cork cells arranged very loosely, so that air can penetrate between them. In winter the lenticels are closed by close layers of cork beneath them, but in spring these are burst and the lenticels again opened (Fig. 122).

Before the fall of the leaf cork layers are formed at the base, so that when the leaf is torn off, the wound is, so to speak, healed before it is made.

When the internal parts of a plant are wounded, so that the cambium is laid bare, this gives rise to a mass of tissue known as callus, in which cork is usually developed later.

Structure of the Leaf.

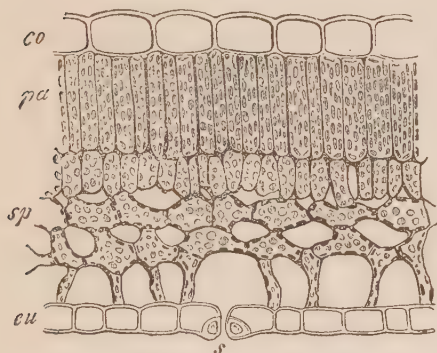
A leaf consists of veins, and of parenchymatous tissue. The veins are formed by the fibrovascular bundles. These run out to the edge of the leaf, branching and getting thinner and thinner till they end below the epidermis in one or two spiral tracheides. Often a mass of large parenchymatous cells, forming what is called a water gland, intervenes between the end of the fibrovascular bundle and the edge of the leaf. There is then a water pore in the epidermis over the gland, which is like an ordinary stoma, only that it is larger and not capable of opening and closing. Issuing from these, drops of water may be seen early in the morning, especially in *Alchemilla*.

The stomata are much more numerous as a rule on the under than on the upper side of a leaf, and in accordance with this we find many more intercellular spaces amongst

the cells of the lower part. The cells under the upper epidermis are oblong and closely packed, forming what is called the palisade parenchyma, while the loosely packed, irregular cells of the lower part form the spongy parenchyma. The cells forming the mesophyll of the leaf are crowded with chlorophyll corpuscles.

A leaf with the above arrangement is called bifacial. Such leaves as those of *Pinus*, on the other hand, are centric, being the same all round, with no distinction between palisade and spongy parenchyma.

FIG. 123.



Transverse section of a Beech leaf (mag. 350).

co, epidermis of the upper side.

cu, epidermis of the under side.

pa, the palisade parenchyma.

sp, spongy parenchyma.

s, stoma.

Hairs.

It has already been stated that the hairs of a plant are outgrowths of the epidermis. The most important are the unicellular hairs developed by the epidermis of the root at a little distance behind the apex. Hairs are more often, however, multicellular, *e.g.* Sunflower; or even consist of masses of cells forming quite large scales, as in Thistle. In glandular hairs a sticky fluid is secreted under the cuticle. In Sundew this excretion is a digestive fluid.

PRACTICAL WORK.

Epidermis.

1. Tear off a piece of the cuticle of a leaf of Hyacinth. If none of the parenchyma from below adheres, the specimen will be colourless and transparent, and will show very clearly under the microscope the shape of the epidermal cells, and of the stomata with their guard cells.

2. The development of the stomata may be traced by tearing the cuticle down to the base (at which growth is longest continued) of a young leaf.

3. Similarly treat the leaf of a Dicotyledon such as Violet, and compare.

4. Make sections of the leaves, and observe the epidermal cells in section. The stomata are now much less conspicuous. In the epidermis of leaves of Pinus they are more striking, being recessed. (Note in Pinus at the same time the resin ducts and the centric arrangement.)

5. Cut sections of a leaf of Indiarubber, and observe the many-layered epidermis, distinguished from the mesophyll below by being colourless. At the same time note the large cells containing cystoliths. Treat with weak acetic acid till the cystoliths dissolve, leaving only a club-shaped process of the cell-wall.

Fundamental System.

6. Cut transverse sections of a herbaceous stem, such as that of Sunflower. Treat some of the sections with Schultze's solution, and observe—

The cells of the epidermis—the cuticle stains yellow, the rest of cell-wall blue.

The multicellular hairs, each of which is the apex of an

emergence of the tissue beneath. *N.B.* the epidermis of Sunflower is exceptional in containing a certain amount of chlorophyll.

The fundamental tissue, forming the cortex of the stem, and the pith. Immediately below the epidermis is the hypodermis, of the variety known as collenchyma, with cells thickened where three meet. Under the hairs the emergence consists of parenchyma. Internally the cortex is composed of parenchyma cells with pitted walls. The layer bordering on the wood forms an endodermis or bundle sheath. This is shown more clearly in sections of very young stems, and especially of the hypocotyledonary stem, and may be recognised by the black dot on the cell-wall, due to the peculiar thickening.

The pith is composed of parenchymatous cells, whose contents are frequently replaced by air, whence the white colour of the pith. The walls of the parenchymatous and of the hypodermis cells are stained blue, but those of the bundle sheath yellow.

7. Resin ducts are numerous and noticeable. They may also be studied in sections of the leaf of *Pinus*, and are especially clear in stems of *Ivy*.

8. To observe crystals in cells, cut sections of the leaf-stalk of *Begonia*. The crystals here are cubical. (Note also the collenchyma.) Needle-shaped crystals are common in the *Monocotyledons*.

9. Starch grains may be observed by cutting sections of tubers of *Potato*.

10. Latex cells and vessels. When it is desired to observe these, the material—if possible the uninjured plant—must be placed in spirit to harden the latex and prevent it from escaping. To observe latex cells, cut sections of *Spurge*, and stain with iodine. Notice then the dumbbell-shaped starch grains. Latex cells may be dissected out with needles after boiling in potash. For latex vessels cut sections of the root of *Dandelion*, and warm the section in potash to dissolve the surrounding tissues. Examine in glycerine.

Fibrovascular System.

11. Transverse section. Pick out the thinnest of the above sections of stem of Sunflower. With the low power distinguish the bast, opaque and gray-looking if unstained, because of the thickened walls and small openings of the bast fibres—the wood, with large clear openings and very distinct cell-walls—and the thin-walled cambium between. Observe that the bundle is collateral.

With high power make out more distinctly—

The small thickened walls of the hard bast (bast-fibres), staining yellow.

The larger openings of the bast parenchyma and sieve tubes, with thin walls, staining blue. Sometimes a sieve plate just happens to come in the section.

The cambium cells, thin-walled, staining blue, with numerous tangential walls, showing how rapidly they divide.

The wood vessels, empty of cell contents, walls variously thickened and staining yellow. The smaller, rounder vessels at the apex of the bundle are the spiral or annular vessels of the primary wood.

The wood fibres appear as small openings amongst the large openings of the vessels. There is very little wood parenchyma in Sunflower.

12. Make careful longitudinal sections, and treat as above.

The characteristic appearance of the sieve tubes will now appear, especially on staining a good section with iodine, when the brown protoplasm will be seen collected round the sieve plates. The various thickening of the wood vessels can also be distinguished. Transverse and longitudinal sections should be carefully compared till the forms of the various cells are understood. Note that the cambium cells are oblong. When parenchyma cells border on empty pitted vessels, ingrowths of the parenchyma into the vessels, through the pits, may sometimes be observed (thyloses).

Observe that the bundles are arranged in a ring, and that except in very young stems, interfascicular cambium has already arisen in the primary medullary rays, and has probably begun to form secondary wood and bast. This is, however, more marked in non-herbaceous stems.

13. Study similar sections of the stem of a Monocotyledon, such as Maize or Hyacinth. There is no cambium. The bundle is surrounded by sclerenchyma, and the most internal vessel, when old, by an intercellular space. The arrangement of wood and bast is generally collateral, with the wood towards the centre of the stem. The constituents are similar to those of Sunflower.

14. Cut sections of young twigs of Elm or Pine and examine the cambium, annual rings of wood, and secondary medullary rays.

15. Sieve tubes are particularly numerous in Vegetable Marrow, and other species of Cucurbita. It is therefore worth while to cut longitudinal sections, and stain with iodine or eosin. The former stains the protoplasm brown, the latter pink.

16. The course of the bundles in the stem can be made out roughly in a stout stem such as that of Sunflower, by boiling a piece of the stem and dissecting away the soft tissue from the fibrovascular bundles. More accurate observations must be made by cutting longitudinal sections through a node and the base of the leaf-stalk. Treat these sections for a few minutes with strong potash, or (better) for twenty-four hours with weak, and examine in glycerine.

17. Cut transverse sections of a young root. The arrangement is radial, and the bundles form an axial mass in both Monocotyledons and Dicotyledons. Hyacinth shows the radial arrangement and bundle sheath very nicely. In roots which increase in thickness, sections of old parts of the root will no longer exhibit the radial arrangement.

The Apex.

18. Cut longitudinal median sections of the apical bud of Sunflower. Treat with potash, and examine in glycerine. The apex is a blunt cone, composed of small cells, and behind it may be distinguished the beginnings of the leaves, the youngest nearest to the apex. Note that the youngest leaves and the apex are free from hairs, which are developed later from the dermatogen, which becomes developed immediately behind the apex. The periblem and plerome arise from a common meristematic mass a little behind the apex in Sunflower. Trace the connection with the mature tissues.

19. Similarly cut longitudinal sections, which are useless unless accurately median, through the radicle of Sunflower, this being easier to cut than the tip of the root at any other period. The growing point of the root is some distance within the external apex. Immediately behind it the periblem and plerome are distinguishable, and at the same time a single layer, from which arise both dermatogen and calyptogen. In Scarlet-Runner, if similar sections be examined, it will be seen that periblem, plerome, dermatogen, and calyptogen arise at the same time from a common meristem.

Cork.

20. To examine cork and lenticels, cut transverse sections of two-year-old twigs of Birch.

Structure of the Leaf.

21. Cut sections of a portion of a leaf of Sunflower. Observe the epidermis, mesophyll, consisting of palisade and spongy parenchyma, with the cells full of chlorophyll corpuscles. Notice that the stomata open into the intercellular spaces of the spongy parenchyma. Compare the arrangement here with that in leaf of Pinus above.

CHAPTER V.

THE FOOD OF PLANTS.

EVERY living plant, and every part of a living plant, to some degree contains water.

Analyses show that some water plants contain a weight of water equal to 95 per cent. of their whole weight. The proportion in ordinary herbaceous plants is about 60 per cent., and even such organs as ripe seeds contain about 12 per cent.

Microscopical examination shows that the living cells of a plant consist of a closed membrane, the cell-wall, which is kept stretched by the water which saturates the protoplasm of the cell, and fills the vacuole. It is a familiar fact that no plant grows when in a flaccid, withered condition. Healthy cells are kept stretched—that is, turgid—by the water which they contain.

The water may be driven off at a temperature a little above boiling-point, leaving behind a dry residue. This consists of a variety of substances, which have been formed by the vital activity of the plant, and which chemical analysis shows to consist of the elements carbon, oxygen, nitrogen, hydrogen, sulphur, and phosphorus, variously combined to form such substances as proteid, cellulose, starch, fat, etc. In combustion all these organic compounds are resolved into carbon dioxide, water, and ammonia, leaving a white mineral ash. This ash contains at different times small quantities of a great number of the elements, but it has been proved that the only ones whose presence is essential to the life of the plant are—Phosphorus, and the metals Potassium, Magnesium, Calcium, and Iron, and (in certain cases only) Chlorine.

We must now consider the mode of absorption by the plant of these essential elements, and, later on, the way in which they are built up into the cell-wall and protoplasm of which plants consist.

Since water forms such a large percentage by weight of the whole plant, and since, moreover, it has been proved that plants take up all the rest of their food in solution in water, we shall first consider the absorption of water and its passage through the plant.

Absorption of Water.

In the case of simple plants such as *Protococcus* and *Yeast*, it is evident that all their food must be absorbed through their cell-walls from the water in which they live. In higher plants the power of absorption is specially manifested by a particular set of cells, viz., for gases in solution, by the cells of the leaves; and for water containing various substances in solution, by the epidermal cells of the roots, particularly by the root-hairs.

Roots are generally much branched, and the younger parts are covered by thin-walled, unicellular root-hairs. Thus a great surface is exposed to the soil in which the plant is growing, and the particles of soil come into very close contact with the roots. Each particle of earth is coated by a thin film of hygroscopic water, even when the soil appears dry, and when it is wet all the channels between separate particles are filled with water. Thus the water saturating the soil is only separated from that saturating the cells of the root-hairs by a thin membrane, the cell-wall.

It is found that all liquids capable of wetting a membrane are also capable of diffusing through it, by a process known as osmosis. The rate of diffusion depends on the nature of the two liquids. For example, if a little drum, containing a strong solution of sugar, be floated on the surface of water, diffusion takes place through the membrane. After a time, the water outside the drum will be found to contain sugar, but at the same time water has diffused into the drum, and

more rapidly, for the fluid within will be found to stand at a higher level than before. Sugar is therefore said to have osmotic attraction for water. Alcohol and other substances exhibit the same power even more strongly.

We shall then expect to find osmosis going on between the water inside and outside the membrane of the cell-wall.

Since the cells are kept constantly turgid, they must contain osmotically attractive substances. Besides sugar and mineral salts, which have an attraction for water, the cell-sap contains vegetable acids, such as malic acid, etc., which are strongly osmotic, and thus water is constantly being absorbed into the root-hairs.

We must remember that the cell-wall has a lining of living protoplasm. It seems probable that the action of this is on the whole to prevent diffusion out of the cell, while allowing the entrance of water, so that it helps to keep the cells distended.

There will also be a certain tendency for the mere hydrostatic pressure of water outside to force water into the cells if the pressure there falls below that outside.

Owing, then, to the osmotic attraction for water of substances in the cell-sap, to the action of protoplasm in preventing loss of water, and to the pressure of water from without if the pressure within falls below that without, the epidermal cells of the root are kept constantly distended with water, *e.g.*, they are kept turgid.

Then, in precisely the same way water is passed from cell to cell of the parenchymatous cortex till the whole is equally turgid. Should any cell contain little water, its cell-sap will contain a more concentrated solution of osmotic substances than neighbouring cells, and will attract water; also the pressure of water in neighbouring cells will be greater, and will cause water to be forced in. Thus equilibrium of water will be established, and at once regained if disturbed.

The importance of the root-hairs will now be manifest. It is illustrated by the fact that a plant withers at first when transplanted, its root-hairs having been torn off.

Experiments have been made which show that water

is conducted upwards to the stem and leaves chiefly by the wood. Since the vessels and fibres of wood are mere skeletons, destitute of protoplasm, it is evident that the process by which water is conducted upwards by the wood must be of an entirely different character from that by which it is absorbed by the parenchyma of the roots.

The turgid parenchyma cells bordering on the wood force water, by mere pressure, into the wood cells, until, at some periods of the year, they are quite full of water, and even water is forced upwards with a variable, but very considerable, pressure. This is shown in the "bleeding" of certain plants. If a young stem of Vine or Birch be cut across in early spring, water issues from the cut wood vessels with considerable force, which may be measured by connecting the cut surface with a manometer tube. Also drops of water may often be seen to exude from the water pores of leaves. This pressure of water in the plant depends on the absorbent activity of the root, and is therefore called root-pressure. By it water is forced into the walls of the wood vessels, which easily take up water, and afterwards up through the wood to supply the upper parts of the plant. It is not certain exactly how it travels, but probably in the walls of the wood vessels. It supplies the parenchymatous tissue of the upper parts, and, even when excessive, causes the exudation of water in drops at the end of the fibrovascular bundles at the edges of the leaves. The medullary rays serve the purpose of taps at intervals, by which supplies of water may be drawn off to supply intermediate tracts of parenchyma. The parenchyma of the upper parts is kept turgid by the passage of water from cell to cell until equilibrium is established, in the same way as that already described for the parenchyma of the root.

Root-pressure varies considerably according to circumstances. It rises in the morning, and falls again in the evening, even when there is no change of temperature. During the summer, when the leaves are expanded the plant is as a rule losing water very rapidly by evaporation into the air of the intercellular spaces of the leaf, which are in

communication with the outer air by means of the stomata. This process is called transpiration. Often when water is being lost rapidly in this way, the activity of the root is not great enough to set up any root-pressure. On the contrary, when very rapid evaporation is going on, the loss may be greater than the supply, and then water will be sucked into the wood vessels, instead of spurting out if the stem be cut and connected with a manometer tube. When transpiration is going on, the interior of the wood vessels is always empty of water.

Thus, in summer, two causes work side by side to facilitate the passage of water through the plant.

(1) The osmotic activity of the root-hairs and parenchyma cells of the cortex of the root causes absorption of water sufficient to maintain these cells perpetually in a turgid condition. They then, by the pressure of water within them, while the wood cells are empty, force water into the walls of the wood vessels by filtration, and up them with a varying pressure. Here the source of activity is in the roots, and the tendency is to force water upwards from below.

(2) When transpiration is going on, the cells in the leaves are losing water to the surrounding air. They would become withered only that they absorb water from neighbouring cells, those in their turn from others, and so on through the plant. Thus a suction current is set up towards the leaves. The source of activity is in the leaves, and the tendency is to suck water upwards from below.

The amount of transpiration going on from the leaves depends on the temperature of the surrounding air, and on its dampness. It is always greater in the light, which must be connected with the fact that the stomata open in the light and close in the dark. It is also increased by mechanical disturbance, as when leaves are waved to and fro in the air.

Absorption of other Food Material.

Very numerous experiments as to the growth of plants under varying conditions, and with varying supplies of food,

have led to the following conclusions with regard to the mode of absorption of food by plants.

A plant can only take in food in the liquid form. It is evident that all the soluble substances present in the soil will diffuse into the cell-sap of the plant. Unless, however, they are used up in some way, this will soon become as saturated as the water outside, and then no more will be absorbed. Thus all soluble substances present in the soil will also be present in the plant in small quantities, though they may be quite useless to it. Experiments to determine what substances really are necessary have been made by growing seedlings in various solutions, and noting the results. The necessary substances are those before stated. With regard to nitrogen, though there is such a large proportion of free nitrogen in the air, it has been found that none of the nitrogen of the plant is hence derived, nor, in fact, is any free nitrogen absorbed. The lower plants, like *Protococcus*, can take in their nitrogen in the form of the very simple compound ammonia; but the higher plants absorb it almost entirely in the form of nitrates. A nitrate is a compound of oxygen and some metal with nitrogen, in particular proportions. Nitrates are constantly produced in the soil from decaying animal and vegetable matter.

Phosphorus, sulphur, chlorine, and the metals potassium, calcium, magnesium, and iron are found variously combined in the soil. Their compounds are absorbed in solution in the same way as the nitrates. In some cases the compounds in the soil are not soluble in pure water, though they are in a slightly acid solution. In such cases the acidity of the cell-sap, and the presence of carbonic acid gas (carbon dioxide), which, as will be seen later, is constantly being given off by the roots, secures their solution. Some of the necessary elements are known to have a special office. For instance, a plant supplied abundantly with all requisites except iron fails to turn green, and never forms any chlorophyll or starch. Potassium seems to serve a special purpose in stimulating the chemical processes going on in a plant. As the rather

numerous crystals of plants all consist of compounds of calcium, it is thought that this may be of use in forming such insoluble compounds with acids, which might otherwise be injurious. The exact use of all these substances in the economy of the plant is not very well known.

On the other hand, carbon dioxide and water are taken up by the cells of the epidermis of the leaves. In the case of land plants, carbon dioxide is dissolved by the cell-sap from the atmosphere. If compounds of carbon are supplied to the roots, they are absorbed, but the usual source of carbon for green plants is the carbon dioxide of the air. Plants without chlorophyll, however, are obliged to absorb it in combination, whence their parasitic habit.

No plant can exist in a normal condition unless supplied with oxygen to support its respiration. Respiration is much less active in plants than in animals. It is comparatively active in the most important parts of the plant, such as stamens, carpels, and germinating seeds.

PRACTICAL WORK.

Take the weight of a herbaceous plant, such as Sunflower, when fresh. Cover it with sand, and subject it to gentle heat for twenty-four hours, or more, till quite dry. Reweigh, and deduce the proportion of water. Subject the dried residue to a greater heat, till only a small quantity of ash is left.

Examine any well-branched root, and observe its intimate connection with the soil, and especially the way in which the particles of soil adhere to the root-hairs, at a little distance behind the apex, though not to the apex itself, nor yet to the older parts of the root. Clear off all the soil and replant. For some time the plant will wither, till it can form new root-hairs.

Similarly examine seedlings of Mustard. Wash carefully, and observe the extent of surface exposed by the root-hairs.

Test the root-hairs with litmus paper, which will give acid reaction (blue litmus paper turns red). Compare with the effect of lemon juice, where the vegetable acid also turns blue litmus paper red.

An instructive experiment may be performed as follows:—Place a leafy plant in the neck of a vessel filled partly with oil, partly with water. When the tip of the root alone is in water, the rest being in oil, the plant begins to wither; similarly if the old parts of the root alone are in water; but if the root-hair region is in water the plant flourishes, even if all the rest of the root is in oil.

Carry out the experiment in osmosis described in the text: To make the rise of the water more evident, it is better to

arrange matters so that the upper part of the floating vessel is narrowed into a tube.

To show that the protoplasmic lining retains water cut sections of Beetroot and place them in a strong salt solution. Water escapes because of the osmotic attraction of the salt, but the protoplasm contracts round the coloured sap, not one drop of which escapes. On flooding the slide with water the protoplasm is again distended; but if cells are boiled before being treated with salt solution the coloured sap diffuses out at once, showing that it was the living protoplasm which retained it in the preceding experiment.

Cut a Potato tuber in half, and expose the surface to the air. It will gradually wither inwards from the cut surface till the whole is withered.

Remove the cortex from a growing plant, leaving the wood intact; the upper part remains fresh. If the wood be removed for even a short space, the plant at once withers.

In early spring the phenomenon of bleeding may be observed from the cut surfaces of twigs of Birch, or (better) of Vine or Hop.

To observe root-pressure, take a vigorously growing plant, say of Sunflower, and cut the stem across a few inches above the root. By means of a band of indiarubber attach a glass tube leading to a manometer tube. The space between the cut surface and the surface of the mercury in the manometer must be filled with water. At first probably water will be sucked in, showing that the pressure was negative, but after a little while the water will rise, and the manometer will register an increasing root-pressure, due to the activity of the roots in the absence of transpiration.

Loss by transpiration is observed when a cut branch withers. It may be measured by weighing the branch fresh and withered. Withering is much delayed if the surrounding air is already saturated by water.

Grow a plant over a piece of marble for some months. The outline of the root system will be found eaten into the surface of the marble, this having been decomposed and rendered soluble by the acid given off from the roots.

The food of plants is best studied by a series of water cultures. A suitable solution is given below, and the effect may be tried of leaving out any of the constituents.

Distilled water,	1000.0 grammes.
Potassium nitrate,	1.0 ,,
Calcium sulphate,	0.5 ,,
Magnesium sulphate,	0.5 ,,
Calcium phosphate, }	traces.
Ferrous phosphate, }	

CHAPTER VI.

METABOLISM.

THE chemical changes which go on in plants have for their objects the building up of protoplasm. In an elementary work such as the present the processes of Metabolism can only be briefly outlined.

By the action of the living protoplasm of the cells of the leaves the carbon dioxide (CO_2) and water (H_2O) which are absorbed from the air are combined together into one compound substance, while a volume of oxygen gas is set free equal to that of the carbon dioxide taken in. The nitrates absorbed by the roots are first transformed into other nitrogen compounds called amides, in which form they are easily soluble and pass up to the cells of the leaves, and are then combined with the above carbohydrate substance into proteid. The transformation of this dead proteid into living protoplasm involves the whole problem of life. The above, however, are the stages in the process by which living protoplasm, in presence of sunlight and by aid of chlorophyll, builds up its own substance out of the much simpler materials of its food. The chemical processes which attend the building up of protoplasm are known as constructive metabolism.

Chlorophyll is a green substance, soluble in alcohol, which exists in the plant in very close connection with protoplasm. In all except very simple plants it is confined to special rounded masses of the protoplasm, called chlorophyll corpuscles. Under a high power it is seen that these are composed of a kind of sponge-work, with chlorophyll filling up the spaces. Several theories have been advanced as to the way in which chlorophyll acts. The one which is best supported is that the

chlorophyll absorbs certain rays of light, and thus supplies the protoplasm with energy.

Side by side with the building up of protoplasm we find processes of destructive metabolism constantly going on, whereby protoplasm breaks down into simpler substances. It seems to be part of its vital nature to be in a state of instability, constantly being built up, and as constantly breaking down. In a growing part the constructive processes are in excess ; in a decaying part, the destructive. To accomplish the constructive process the plant requires energy, as one does to carry a stone up a hill. The destructive process sets free energy, just as when a stone rolls down a hill it may set free sufficient energy to knock a man over. The following are some examples of destructive Metabolism .—

(1.) The protoplasm of a living cell is always undergoing slow combustion with oxygen in the process of respiration. The process is rather complicated, but the result is to produce once more the simple substances, carbon dioxide, water, and ammonia. The setting free of energy is shown by the accompanying rise of temperature. The carbon dioxide and water are set free into the air, the ammonia is retained in the plant for future use. Thus, on the whole, in respiration oxygen is taken in and carbon dioxide is set free. The amounts are generally fairly equal, though not necessarily or invariably so.

It has already been stated that in the constructive process carbon dioxide is taken in, and an equal amount of oxygen is set free. Thus in a green plant exposed to sunlight two opposite processes go on side by side. Respiration in plants is, however, so feeble that it is much less conspicuous than the constructive process, so that the result is simply to lessen a little the amount of oxygen given off ; but, in the dark, when the constructive process ceases, respiration becomes evident, and Fungi show it at all times.

The constructive energy of green plants is the only means known by which protoplasm can be built up out of non-organic compounds of carbon. Since animals depend in the

first instance on plants, the carbon dioxide of the air is the ultimate source of carbon to all living beings.

(2.) It has been shown that the cellulose (C and H and O) wall of a cell is derived from the external layer of protoplasm, and is thickened by the repeated breaking down of such layers. Thus the formation and thickening of the cell-wall is another example of destructive Metabolism.

(3.) In the chlorophyll corpuscles themselves the recently formed protoplasm is constantly breaking down into starch (C and H and O). Thus arise the starch grains so constantly to be observed in chlorophyll corpuscles exposed to sunlight. In the above instances it is always the carbohydrate (C and H and O) part of protoplasm which is set free. The nitrogen part, in the form of compounds called amides, is at once used up to combine with fresh carbon dioxide and water in a new constructive process.

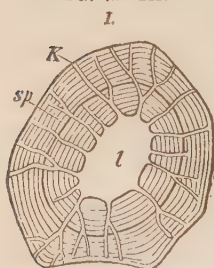
Besides the above examples of destructive Metabolism, there are many others which cannot be touched on here. We pass on to consider the transport of food material from one part to another, and the way in which it is stored up for future use.

New material is constantly being manufactured in the leaves, but is required either in the growing parts, where fresh cells are being formed, or in the storage organs, such as roots, bulbs, tubers, seeds, etc. We have said that protoplasm, in the very cells where it is built up, splits into starch, which is a carbohydrate containing carbon, hydrogen and oxygen, and an amide containing nitrogen. Starch is insoluble, and is deposited in the form of starch grains; but after a time it is converted by a process of fermentation into sugar, also a carbohydrate, but which, being soluble, can pass easily by diffusion from cell to cell. Amides are soluble. If, then, sugar and amides are being used up in any part of the plant, so that certain cells contain none, a current will be set up, as before explained, towards that part. In the growing parts and storage organs sugar and amides *are* being used up to form fresh protoplasm, and so a current *is* set up from the

leaves towards those parts. In the growing parts the fresh protoplasm forms new cells, some of it breaking down to form the new cell-walls. In the storage organs protoplasmic bodies are formed similar to chlorophyll corpuscles, but colourless, which are called leucoplasts. These constantly break down and form starch grains in the same way as the chlorophyll corpuscles do, but these starch grains grow to a very much larger size. The cells of starchy roots and tubers become quite filled up with large starch grains. The cells of storage organs sometimes contain amides, but more often the nitrogen is stored up in the solid form. It is probably also often transported in the solid form down the sieve tubes of the bast. Such solid proteid material forms small oval grains called aleurone grains. In oily seeds starch is replaced by drops of oil, which also consists of carbon, hydrogen, and oxygen. In this case the aleurone grains are generally larger. Occasionally sugar is stored up, as in Onion, instead of starch.

When the upper parts begin to grow, or when seeds germinate, the above process is repeated in reverse order. Starch is converted into sugar, and conveyed with the amides to parts where fresh protoplasm is being formed. When the

FIG. 124A.

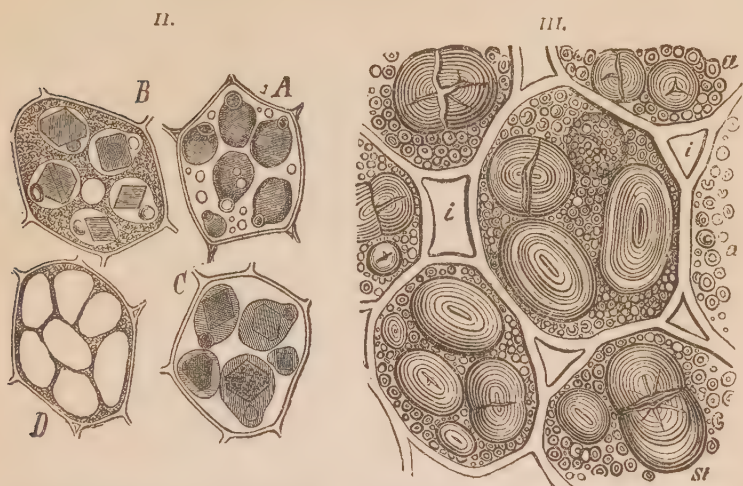


l—Section of a cell showing stratified cell-wall, K, pits in wall, l, opening of cell.

reserve material is in the form of oil, this is generally converted first into starch and then into sugar. The aleurone grains are dissolved and supply ready-made proteid.

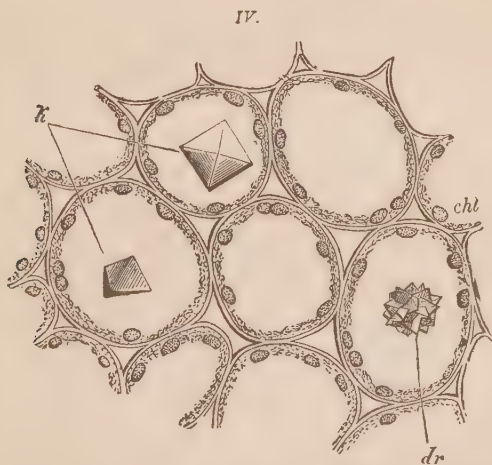
Starch grains are always found in connection with protoplasm. They vary in shape, but are always stratified. The layers differ in the amount of water they contain, and are always arranged round the least dense part of the grain, called the hilum. The grains are increased, as cell-walls are, by the breaking down of the layer of protoplasm immediately in contact with them. Sometimes two grains will come into contact,

FIG. 124B.



II.—Section of cell containing aleurone grains and oil drops; A, B, C, D, stages in solution of the grains.

III.—Section of cells containing large starch grains and small aleurone grains; a, aleurone grains; i, intercellular spaces; St, starch grains.



IV.—Transverse section of the leaf stalk of *Begonia*; chl, chlorophyll corpuscles; k, solitary crystals; dr, cluster of crystals of calcium oxalate.

and successive layers be formed common to the two, giving rise to compound grains. Aleurone grains are oval in shape, and consist of two or three different kinds of solid proteid material, collected round a small body called the globoid, which consists of magnesium phosphate. Part of the proteid material often forms a crystalloid mass. Sometimes true crystals are also present.

The chemical changes which go on in plants are arrested at a very low temperature, and proceed best at medium temperatures, varying with the nature of the plant. All life is destroyed by continued boiling.

Cells can recover after freezing, even though they may be injured and split by the ice crystals, if not thawed too rapidly for the water to be reabsorbed.

PRACTICAL WORK.

To show that a plant in the dark takes in oxygen and sets free carbon dioxide, place a freshly gathered branch bearing leaves under a stoppered bell-jar, under which is also a saucer of caustic potash. Let the bell-jar be closed by a cork, through which passes a funnel leading into the caustic potash, and also a tube leading to a manometer tube. After some time decrease of pressure will be shown, due to the absorption of oxygen in the respiration of the plant. The carbon dioxide produced is absorbed by the caustic potash. If a little hydrochloric acid be added by means of the funnel to neutralise the potash the carbon dioxide is set free, and the manometer will register an increase about equal to the preceding decrease.

To exhibit the manufacture of oxygen by a green plant in sunlight place a branch in a wide tube closed at one end. Fill this with water, and invert it in a dish of water. Bubbles of gas arise from the leaves and collect in the upper part of the tube. When enough gas has collected, it can be tested with a glowing match, and thus be proved to be oxygen. The experiment succeeds better if the plant be supplied with carbon dioxide by introducing a little seltzer water.

To see the starch grains in chlorophyll corpuscles:—Place green leaves in alcohol till all their chlorophyll is dissolved. Cut sections. Treat with potash (which causes the grains to swell), and stain with iodine. Starch grains are then seen, stained blue. After a little while the protoplasm stains brown, and the grains become less evident. Starch grains vary much in size in different plants, and are therefore much

easier to see in some cases than in others. Leaves of *Funaria Hygrometrica*, or the prothallus of any Fern, are recommended as good material.

Leucoplasts are comparatively easy to see in the rhizome of *Iris Germanica*. Take surface sections after removing the most external layers. Mount in water, and examine for amyloplasts, to which are attached one, or often two starch grains.

To observe aleurone grains, cut sections of a Brazil Nut. Lay the preparation in water (which, however, gradually dissolves part of the grains). On adding absolute alcohol the crystalloid comes out very clearly. A globoid is also present.

Stain other sections of Brazil Nut with 1 per cent. osmic acid. First the oil drops, and then the protoplasm will turn black.

For the micro-chemical reactions, by which transference of food material can be traced, the student is referred to more advanced books, such as Strasburger's *Practical Botany*, etc.

The rise of temperature which accompanies destructive Metabolism may be observed as follows:—A funnel filled with germinating seeds, say of Pea, is placed in the neck of a bottle containing caustic potash. The whole is covered by a stoppered bell-glass, through the plugged neck of which passes the stem of a thermometer, whose bulb is buried amongst the seeds. The carbon dioxide produced is absorbed by the caustic potash. If a similar arrangement be set up side by side with this, with the seeds replaced by bits of paper, the difference of temperature of the two thermometers will then show very clearly that heat is generated by the chemical processes going on in the germinating seeds.

CHAPTER VII.

GROWTH.

By growth we mean permanent changes of form, which are generally accompanied by increase of size and weight—that is, by a manufacture of new material.

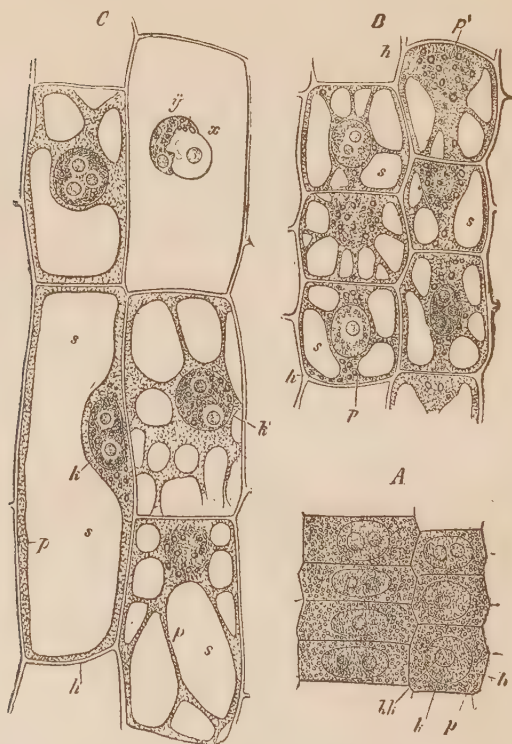
We have already seen that growth depends on a supply of food material, a certain favourable degree of temperature, enough water to render the cells turgid, and on certain processes of Destructive Metabolism, involving, as a rule, the absorption of oxygen. Besides all these external conditions, growth depends on the inherent capacity of the cells themselves. A cell continues to grow for a certain period, but, after that, no matter how favourable circumstances may be, growth becomes less active and finally ceases.

First, to consider the growth of individual cells. At the beginning the whole interior is filled by protoplasm, and its growth causes stretching of the cell-wall. Then the external layer of protoplasm is converted into cellulose, which is added to the cell-wall, so that the stretching is rendered permanent and the cell grows. Later vacuoles—that is, spaces filled by cell-sap—begin to arise, and increase till they coalesce to form a large central vacuole. The protoplasm thus comes to form only a lining to the cell-wall, but, owing to the turgidity of the cell, the cell-wall continues to be stretched, and goes on growing.

Sometimes the cell grows equally in all directions, but more often certain parts become more extensible than others, and are pushed out so that the cell may assume a variety of

forms. This is probably due to the action of the protoplasm, which is always in contact with the cell-wall. It is not known fully how protoplasm itself grows, but probably the processes of growth go on throughout the whole of its substance.

FIG. 125.



A, B, C.—Stages in the development of parenchymatous cells; *h*, cell-wall; *p*, protoplasm; *k*, nucleus; *k'*, nucleolus; *s*, vacuole; *x, y*, contracted protoplasm.

When we come to consider growth of organs and masses of cells, we find that growth only continues in certain parts, found generally at the apex, but sometimes at the base of

an organ, as in leaves. At the very apex of a growing organ is the growing point itself, where the cells remain small, but increase rapidly in number. Behind this is a region where the cells, without dividing, increase very greatly in their size.

It is characteristic of growing organs that they are very easily affected by external events, such as changes of light and temperature. They are also, as a rule, very easily bent, and they are called inelastic because they remain bent for a long time. Thus if a growing stem be sharply struck, it becomes curved, and remains so for some time.

When growing organs consist of different tissues they are all under tension, turgidity being an essential of growth, but some more so than others. Thus the pith and ground tissue remain thin and extensible, while the epidermis and fibrovascular system become thick-walled and rigid comparatively early, and in consequence the ground tissue, and especially the pith, tend to pull out and extend the other tissues while they oppose this. The tensions thus set up affect the growth of the cells composing the tissues, making those of pith short and broad, and those of the fibrovascular system long and narrow. Pith also tends to expand transversely, and thus sets up a tension from without inwards, which is resisted by the outer comparatively rigid tissues. Again transverse tensions are set up when a stem increases in thickness by the formation of new tissue from the cambium. This causes a pressure from without inwards on the pith and the wood, and from within outwards on the cortex. These tensions affect the size and form of the wood cells, those formed in autumn, when the external pressure is greatest, being smaller and flatter than those formed at the beginning of the season. All these tensions are much greater in stems than in roots.

The fact that branches increase in thickness much more when freely swayed about by the wind, may be explained by remembering that this swaying loosens and splits the cortical tissue, and thus relieves the pressure on the

wood. On the other hand, the formation of wood may be lessened by wrapping tissue lightly round a growing branch. The tensions set up sometimes cause twisting of the tissues.

It is interesting to notice that when the pitted vessels of the wood lose their contents, and are no longer turgid, the cell-walls of the neighbouring parenchyma cells, being subject to pressure from within, and no longer liable to it from without, are forced through the thin places of the pits, and thus grow into and sometimes fill up the vessels, as described before.

It has already been stated that the growth of a cell is limited to a particular period of its life. During this period the growth is at first slow, then more rapid till a maximum is reached, after which it is slower and slower till it finally ceases. This series of changes is known as the grand period of growth, and is also exhibited by multicellular organs. In a stem we find the youngest part at the apex, and this part increases in size but slowly. Lower down we find zones of tissue increasing in size more and more rapidly, till a part is reached where growth is at its maximum. In zones below this the activity is not so rapid, and declines till parts are reached which no longer grow at all. As a matter of fact, each zone passes through all these stages. When first formed it lies immediately behind the apex, and its increase in size is slow. As fresh tissue is formed it is left further and further behind, and at the same time as it gets older the rapidity of its growth increases to a maximum, and then declines till it finally ceases.

It must be remembered, however, that all the cells in a particular zone need not be growing at the same rate, and, as a matter of fact, frequently are not. In a great many plants it may be observed that first one side of the stem and then the other grows more rapidly. When this is the case the apex of the stem oscillates from side to side. Such motion is known as nutation. Very often the wave of more rapid growth travels round and round the stem, so that the apex

is directed to all the points of the compass in succession. This is known as revolving nutation.

The rapidity of nutation varies in different plants, as does also the length of the stem affected. The following figures, copied from Darwin's observations, will show this.

Plant.	Time of one complete revolution.	
	Longest.	Shortest.
	h. m.	h. m.
Hop (stem nutating 15 in.),	2 20	2 0
Wistaria Chinensis,	3 21	2 5
Ceropigia Gardnerii (stem nutating 31 inches long),	7 55	5 15
Adhobada Cydonæfolia,	48 0	26 30

FIG. 126.

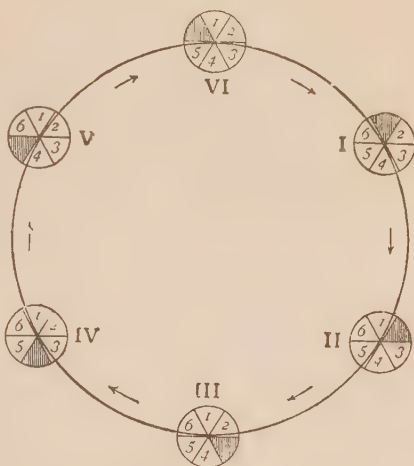


Diagram illustrating revolving Nutation.

Other organs, such as leaves, exhibit movements of the same nature as nutation. Leaves are called dorsiventral, because their two surfaces are not alike. In most leaves the dorsal surface at first grows more rapidly, so that young leaves are more or less folded over to form buds. Later on, as in nutation, the other side grows more rapidly and the leaf unfolds. When the back, or dorsal side, is growing more rapidly the organ is sometimes said to be in a state of hyponasty; when the front, or ventral side, grows more rapidly it passes into a condition of epinasty.

PRACTICAL WORK.

Cut sections close to the apex of a root, $\frac{1}{8}$ of an inch above, $\frac{1}{4}$ of an inch above, and so on, to observe cells in successive stages of growth.

To observe longitudinal tensions divide a young stem into four by longitudinal cuts. The segments will diverge and bend outwards, showing that the pith tends to elongate, and the external tissues to contract.

To observe transverse tensions take a thick transverse section and divide it into halves. The cut edges will become convex to one another, showing again that the pith tends to expand, and the other tissues to contract.

Remove a layer of the cortical tissue from a growing stem, and then try to replace it. It will be found too short, the internal tissues having expanded as soon as pressure was taken off.

To observe periods of growth take a young seedling of Broad Bean, which has germinated in damp sawdust till the radicle is about an inch long. Draw lines in Indian ink across it at equal distances of 1 mm., beginning as close to the apex as possible. Fasten the seed to a cork with a pin, and support it with the tip of the root dipping into water. Measure the lengths of the originally equal intervals, and enter the results in a tabular form, which will illustrate the remarks in the text. Similar experiments may be tried on young stems.

Hop and French Bean are good plants on which to observe nutation. Take young growing plants, and observe and record the direction of the stem at frequent intervals.

CHAPTER VIII.

IRRITABILITY—THE RESPONSE OF GROWING AND MATURE ORGANS TO STIMULATION.

It is one of the most striking properties of protoplasm that it is irritable; that is, that it is sensitive, and responds to the action of external influences.

In considering further the conditions under which cells are irritable, it must be observed that certain conditions of light and temperature are necessary to health. Besides this, however, light and temperature, and especially sudden variations in these, have a direct irritating influence.

Irritability is, in certain cases, manifested by movement. Movements, however, are only possible in parts whose structure allows them to change their form, such as the growing parts. The energy requisite for the movement is supplied by that set free in the breaking down of protoplasm. Even apart from external influences the energy of destructive metabolism is sometimes manifested in irregular, spontaneous, movements such as nutation, which is an example of what is called the automatism of protoplasm. (*See Chapter III.*) Spontaneous movements, due to the inherent vitality of the organism, may be interfered with or stopped by the action of external influences.

Growth itself is a slow movement, with, as we have seen, spontaneous variations, and its rate is affected by external conditions. It is increased by variations in temperature. We find a good example of parts sensitive to change of temperature in the perianths of many flowers. It has been observed that flowers of *Crocus*, etc., respond to a rise of

temperature by opening, and it is said that, in opening, the whole petal grows, though the inner side grows most. A fall of temperature is also responded to by an increased growth, but this time the outside grows most, and the flower closes. Also, apart from changes in temperature, flowers respond to alternations of light and darkness by opening and closing, showing that variations of intensity of light as well as changes in temperature have a stimulating effect. We get a very good example of response to variations of light in Pimpernel, the Shepherd's Weather-glass, which closes its petals if the sun goes behind a cloud.

Besides the above effect of sudden variations of temperature and light, the continued action of external influences affects growth. With regard to the amount of growth, there is for each plant a temperature at which it grows best. Also growth is very much affected by the continuous presence or absence of light; in fact, plants grown in the dark pass into the peculiar condition known as etiolation. Their stems are then very long and flexible, their leaves small and imperfectly unfolded, the whole plant wanting in chlorophyll. From a study of etiolated plants it appears that light retards their growth. This is confirmed by measurements of the growth of a plant throughout a day and night. Growth is thus found to be more rapid in the early morning, as a result of twelve hours' darkness, and least rapid in the evening, after twelve hours of illumination. The fact that the effect of darkness is only shown after a considerable time, and when daylight is returning, shows that the response is not immediate.

Again, it has been found that gravity slightly retards growth, as also does pressure. This explains why the roots of a seedling coming in contact with a stone are able to curve round it. That traction promotes growth is shown by the fact that trailing stems growing in a stream are longer when the current is rapid than when it is slow. Pressure sometimes has a stimulating effect; for instance, the adhesive discs

by means of which the Virginian Creeper climbs are not formed unless the plant is in contact with a solid body. Also tendrils become much thicker after they have clasped a support.

The direction of growth, as well as its amount, is influenced by external conditions. Plants appear to have an inherent tendency to continue their growth in a straight line, and the growth of lateral branches is, in the first instance, relative to that of the part from which they spring.

Organs such as roots and stems which are symmetrical round a centre, are called radial. The effect of light on nearly all radial organs is to cause them to bend out of the straight line either towards or away from the source of light. Such bending is known as Heliotropism. An organ which bends towards the source of light is positively heliotropic; one which bends away from the light is negatively heliotropic. The former is much the more common case, and it is probable that all cases apparently instances of the latter may be explained by special circumstances. Most roots, and some stems, are very little, if at all, heliotropic, but most stems are distinctly so. Positive heliotropism is effected by the side towards the light becoming less turgid, and, therefore, growing less rapidly than the opposite side. The amount of bending depends on the intensity of the light, and on the angle at which it strikes the organ.

When light falls on a dorsiventral organ, such as a leaf, it always induces epinasty; that is, the ventral surface grows most rapidly. Accordingly, if light is directed on the dorsal side of a leaf, it curves away from the light; if on the ventral side, it curves towards the light; the cause being, in both cases, the excessive growth of the ventral surface. The same effect is produced if the light falls on the edge of the leaf, so that is not a case of heliotropism, turning to the light, at all. Dorsiventral organs are, however, influenced by light to take up different positions. As may easily be observed, leaves

always arrange themselves that their upper surface may be perpendicular to the incident light, so that the upper surface of a leaf is generally, though not always, presented to the sky. This peculiar directive action of light on leaves is sometimes called *diaheliotropism*.

Gravitation is a second factor in determining the position of an organ. Certain organs, of which roots are the chief examples, react to gravitation in such a way that in all parts of the world they tend to grow downwards towards the centre of the earth in obedience to gravitation. These are called *positively geotropic*. Others, like most stems, tend to grow in exact opposition to gravitation, and are called *negatively geotropic*.

By fixing seedlings to the circumference of a wheel in rotation, gravitation may be exactly neutralised by centrifugal force. The organs then grow quite irregularly, showing that their usual direction is due to the influence of gravitation. If, however, the speed is increased, so that centrifugal force becomes much stronger than gravitation, the roots which are *positively geotropic* grow out in obedience to centrifugal force; and the stems, which are *negatively geotropic*, grow to the centre of the wheel, in exact contradiction to it. The organs thus behave to centrifugal force as they previously did to gravitation. This is known as *Knight's Experiment*.

If a seedling be laid horizontally, the root curves downwards and the stem upwards, the curvature being due, as before, to a loss of turgidity on one side, followed by less rapid growth on that side, with an increase in growth and turgidity on the opposite side.

Rhizomes and dorsiventral organs under the influence of gravity appear always to assume a horizontal direction; and this directive action may be called *diageotropism*. Branch roots are very feebly *positively geotropic*.

The position of any organ depends very largely on its original direction and its weight.

It is interesting to notice in passing certain other influences which direct growth. Thus organs grown in a current of

water always grow on the whole parallel to the current, and those in a current of electricity likewise. Again the substratum has an influence, the primary shoots placing themselves at right angles to this, whatever may have been their original position. Last, but not least, we must mention the directive influence of neighbouring moisture. Roots will curve in the direction of water in contradiction to gravitation—even upwards into a moist atmosphere, if the soil is dry.

It was believed by Darwin, and is supported by much evidence, that it is the tip of the root which is sensitive to the above influences, and that the stimulus received there is transmitted to the parenchyma cells behind the tip.

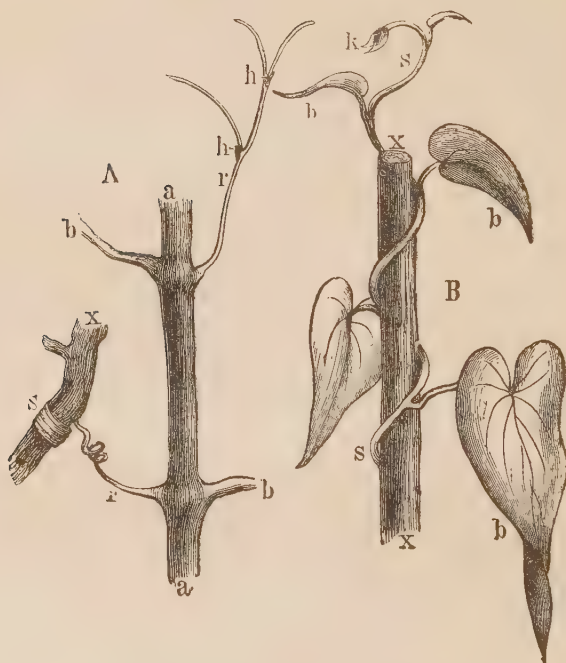
In young organs growth speedily renders all such curvatures permanent.

In some plants special parts, such as tendrils, develop a peculiar degree of sensitiveness to contact. Tendrils are usually modified leaflets, and they nutate, as do also the petioles bearing them. The chances are therefore very great that a tendril will come in contact with some support. A very slight contact produces a curvature, the side touched becoming shorter than the other. The curvature brings fresh parts of the tendril into contact with the support, and so it extends until the whole of the tendril, from the point where it was touched to the end, is coiled spirally round the support. The stimulus is also conducted along the tendril in the opposite direction, and the lower part coils into a spiral wound the opposite way. Thus tendrils attach the rest of the plant firmly, and yet not rigidly, to the support. The end of a tendril is hooked, and the inside of this hook is particularly sensitive. Though it requires but very slight pressure to produce the curvature, tendrils do not seem to be sensitive to contact with other tendrils; nor to drops of rain. If a tendril fails to meet with any support, it generally coils up spirally all in one direction, and then withers and drops off.

In some cases the petioles of leaves are sensitive to contact,

and coil round a support, just as tendrils do. And again many stems are more or less sensitive in the same way, *e.g.* Hop. Their circumnutation brings them into contact with a

FIG. 127.



A.—Part of the stem of the Vine ($\frac{1}{2}$ nat. size) with two tendrils, *r, r*; the upper one bears small leaves, *h*, and branches; the lower one has become attached to a support and has rolled up spirally; *b, b*, petioles; in this case the tendrils are branches which are peculiar in that they are opposite to the leaves.

B.—Twining stem of *Ipomoea*, *s*, with leaves, *b*, and a bud, *k*; *x*, is the support.

support, round which the free portion then revolves. Such a twining stem becomes closely applied to its support by curvatures produced by contact. Twining cannot take place

unless the thickness of the support is adapted to the length and thickness of the twining stem.

The resultant position of any organ is due to the combined effect of all the above influences, so that the complete explanation in any particular case is a complicated matter.

FIG. 128.



Right, and left-handed twining.

Finally we must mention the movements unaccompanied by growth which are sometimes exhibited by fully grown organs.

In this connection the spontaneous movements exhibited by the protoplasm of cells in such cases as motile *Protooccus* and the zoospores of *Vaucheria* must be recalled.

The spontaneous movements of higher plants are most often shown in the leaves.

FIG. 129



Leaf of Telegraph Plant.

The best instance is afforded by the Telegraph Plant, first described by Lady Morrison. The leaves of this plant are compound, and consist of one large terminal and two small lateral leaflets. The lateral leaflets are in constant motion, waving up and down. They move through two right angles in about two minutes. The rapidity

of the movement depends on the temperature, but is independent of light. A similar power of spontaneous move-

FIG. 130



A.—Waking Sensitive Plant.

B.—Sleep position of leaves of Sensitive Plant.

ment is possessed by many plants, particularly by those of the order Leguminosae, but it is interfered with in most cases by the influence of light.

Besides such spontaneous movements there remain those due to stimulation. The most marked of these are induced by alternations of light and darkness. Many leaves—for example, those of the Sensitive Plant—take up a peculiar position in the dark, known as their “sleep” position, because it is assumed at night, though it may be induced by darkness at any time. The terminal leaflet of the Telegraph Plant has a sleep position, though the lateral leaflets continue their movements just the same in the dark as in the light.

FIG. 131.



Leaf of Sundew.

Many leaves, notably those of the Sensitive Plant, are also responsive to mechanical and chemical stimulation, the effect of which is to make the leaves assume a position closely resembling their “sleep” position. Other examples of organs sensitive to mechanical or chemical stimulation are the stamens of Berberis, or of Nettle, and the hairs of the leaves of Sundew. These, on being stimulated, curve over towards the centre of the leaf. They are particularly sensitive to chemical stimulation, as by scraps of meat, drops of

milk, etc. Ammonia gas is also a powerful stimulant. The above are only a few examples of numerous similar movements in plants, all of which subserve some end in the economy of the organism. The movements of irritable stamens scatter pollen; the tentacles of Sundew entrap insects, which are then digested by the glandular juice contained in the heads of the hairs (*see* Fig. 131).

With regard to the machinery by which these movements are carried out, it is found that most organs capable of such sudden movements are provided with a mass of parenchymatous tissue, traversed by a delicate fibrovascular bundle, and containing numerous intercellular spaces. On stimulation one side of the tissue becomes less turgid than it was previously, some of the water passing from the cells into the intercellular spaces, in consequence of which the tissue becomes darker in colour. Thus one side shortens and the organ becomes curved.

The effect of the stimulus is transmitted so rapidly through the tissue that some means of transmission seems necessary. Microscopical examination has shown that threads of protoplasm are continuous from cell to cell, through pits in the walls, throughout the whole mass of parenchymatous tissue, which is called a pulvinus. It is believed that the stimulus affects the protoplasm directly, and is transmitted by these threads throughout the organ. Water is probably expelled from the cells because the stimulation produces changes in the protoplasm which render it more permeable, possibly because the protoplasm itself contracts. When the effect of the stimulation wears off, the cells again take up their water, and the organ recovers from its curvature. The curvature of organs other than leaves is effected in a similar manner.

PRACTICAL WORK.

Examine plants which have been grown in the dark, and observe the general characteristics of etiolation.

Heliotropism may generally be observed in plants growing exposed to one-sided illumination, as in a window. The length of both sides should be taken at intervals, to show that both sides are growing, though one grows faster than the other.

Geotropic curvatures may be observed in seedlings placed horizontally on the surface of soil. Root and stem curve round, the first in obedience, the second in opposition, to gravitation.

If seedlings be placed on damp blotting paper, under a bell-glass, the roots will at first curve downwards in obedience to gravitation. After a time moisture will evaporate from the blotting paper, leaving it dry, while the air under the bell-glass becomes moist. The roots will then curve upwards and grow into the air.

The twining of tendrils and twining stems, and the movements of mature organs, should be observed as occasion serves. Dodder, often found parasitic on Furze bushes, etc., is a very good example of an irritable stem.

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